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The Administrative Record Staff

**FINAL
PHASE II RFI/RI WORK PLAN
(Alluvial)**

REVISION 1

ROCKY FLATS PLANT

**903 PAD, MOUND, AND
EAST TRENCHES AREAS**

(OPERABLE UNIT NO. 2)

**VOLUME I
(TEXT AND ATTACHMENTS)**

**U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado**

ENVIRONMENTAL RESTORATION PROGRAM

28 February 1991

ADMIN RECORD

A-0001-000143

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REVIEWED FOR CLASSIFICATION/LICHT
By V. A. Muenchow *(initials)*
Date 4/2/91

**FINAL PHASE II RCRA FACILITY INVESTIGATION
REMEDIAL INVESTIGATION**

WORK PLAN (ALLUVIAL)

REVISION 1

**ROCKY FLATS PLANT
903 PAD, MOUND, AND EAST TRENCHES AREAS
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ENVIRONMENTAL RESTORATION PROGRAM

**U S Department of Energy
Rocky Flats Office
Golden, Colorado**

28 February 1991

Sidebars in this Revised RFI/RI work plan text (Executive Summary, and Section 1 0 through 5 0) denote changes from the Final Phase II RFI/RI Work Plan dated 12 April 1990. Sections 6 0 through 9 0 and Attachment 1 0 through 5 0 were not included in the 12 April 1990 work plan. As these entire sections are new, sidebars are not provided. Text changes made in response to an EPA or CDH comment (Attachment 5 0) are denoted by solid dots in the right hand margin.

EXECUTIVE SUMMARY

This document presents the work plan for the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Remedial Investigation (RFI/RI), of the 903 Pad, Mound, and East Trenches Areas (Operable Unit Number 2) at the Rocky Flats Plant. An initial (Phase I) field program was completed during 1987, and a draft RI report was submitted to the U S Environmental Protection Agency (EPA) and the Colorado Department of Health (CDH) on December 31, 1987 (Rockwell International, 1987a). This Phase II RFI/RI Work Plan presents site-specific plans for further field work to characterize contaminant sources, and the extent of soils, surface water, and ground-water contamination. Also included are plans for human health and environmental risk assessments and a RCRA Corrective Measures Study/CERCLA Feasibility Study (CMS/FS). This work plan is based on results presented in the draft RI report as well as subsequent surface water and ground-water sampling and analysis. In order to fully characterize the location, extent, and orientation of bedrock sandstones and subsequently the extent of contamination within these units, a seismic geophysical program was implemented at Operable Unit Number 2 (OU No. 2). A separate Phase II RFI/RI Work Plan (bedrock) has been prepared and submitted under separate cover presenting results of the ongoing seismic survey and plans for further bedrock ground-water investigations (EG&G, 1991a). The data obtained during the two components of the RFI/RI field work will be combined and presented in a single RFI/RI report. That report will be the basis for the CMS/PS and the baseline risk assessment.

A final Phase II RFI/RI Work Plan for OU No. 2 was submitted to EPA and CDH on 12 April 1990 (EG&G, 1990a). This February 1991 document is Revision 1 of the Final Phase II RFI/RI Work Plan (alluvial) and incorporates agency comments on the 12 April 1990 submittal. Although not required by the Inter-agency Agreement (IAG), Revision 1 was prepared so that final agency comments are reflected in a single document prior to implementation of the Phase II (alluvial) scope of work. This better assures that the RFI/RI and CMS/FS are conducted in accordance with a plan to which all parties are in agreement. It is noted that this plan has also been modified for reasons not associated with specific agencies comments. These changes have been made to "update" the plan with respect to the current understanding of the site, other OU study activities that impact OU Number 2, and regulatory issues. Major changes are as follows:

- Revised geological characterization based on the on-going seismic reflection study
- Addition of a concise site conceptual model
- Elaboration on data quality objectives
- Discussion of all Rocky Flats Plant treatability study programs
- Addition of seven plume characterization wells between the OU and site boundary because of the recent occurrence of contamination in this location

- Elimination of surface water station sampling (except seeps) because the activity is covered by OU Nos 5 and 6 as well as a site-wide surface water characterization program
- Addition of a more extensive surface soil sampling program to assess the mobility of plutonium in the soil/water environment
- Addition of a detailed environmental evaluation work plan
- Elaboration and modification to the discussion of applicable or relevant and appropriate requirements (ARARs)

The 903 Pad, Mound, and East Trenches Areas, located on the east side of the Rocky Flats Plant security area, were selected for investigation because of their suspected relationship to ground-water contamination. Based on existing results, carbon tetrachloride, tetrachloroethene, and trichloroethene are the primary volatile organic contaminants found in the upper hydrostratigraphic unit (HSU) [this includes the alluvium and hydraulically interconnected bedrock sandstone (uppermost sandstone)] ground-water flow system at these areas. Trace elements commonly occurring above background levels in upper HSU ground water include strontium, barium, copper, and nickel, and to a lesser extent chromium, manganese, selenium, lead, zinc, and molybdenum. Also, major cations and anions and total dissolved solids are somewhat elevated above background throughout and downgradient of the 903 Pad, Mound, and East Trenches Areas. Uranium-238 is the predominant radionuclide occurring above background in the upper HSU ground-water flow system, but a few samples indicate plutonium and americium downgradient of the 903 Pad and possibly north of the Mound. An evaporative concentration conceptual model has been advanced that may explain high total dissolved solids, metals, and uranium in ground water at Operable Unit Number 2. This model does not alter the borehole and well placement strategy in the Phase II plan, and its veracity will be tested in the background characterization study.

There is considerable interaction between surface water and ground water. As a result, organic contamination is observed in seeps downgradient of the 903 Pad and in the upper reaches of South Walnut Creek at the Mound Area. Also, there are somewhat elevated concentrations of total dissolved solids, major ions, strontium, zinc, and uranium at many of the surface water stations.

Plutonium and americium occur above background in surface soils. Other radionuclides and trace metals occur at low concentrations and are infrequently above background, but may also be soil contaminants at the 903 Pad, Mound, and East Trenches Areas. Data suggest plutonium and americium were released to soils in the area via wind dissemination during clean-up efforts at the 903 Drum Storage Site. These radionuclides occur in surface soils throughout the 903 Pad, Mound, and East Trenches Areas and other areas downwind to the southeast.

Plutonium and americium are also observed in two seeps (SW-50 and SW-53) downgradient of the 903 Pad and in the upper reaches of South Walnut Creek. This may be attributed to the water from the seeps coming

in contact with surface soils exhibiting elevated concentrations of these radionuclides. This hypothesis will be tested by the Phase II RFI/RI

This Phase II RFI/RI Work Plan for the 903 Pad, Mound, and East Trenches Areas presents results of the Phase I RI, defines data quality objectives and data needs based on that investigation, specifies RFI/RI and CMS/FS tasks, presents a Field Sampling Plan and Environmental Evaluation Work Plan, and provides quality assurance guidelines and a schedule for conducting the work

The overall objectives of the Phase II RFI/RI are source characterization and determination of the magnitude and extent of ground-water and surface water contamination. Boreholes will be drilled into waste sources to characterize any waste materials remaining in place and to assess the maximum contaminant concentrations in soils directly beneath the sites. In addition, ground-water monitor wells will be installed adjacent to some of the boreholes to characterize ground-water quality directly beneath the sites. This plan calls for drilling and sampling 46 boreholes and the installation of 63 "source" monitor wells. One hundred thirty additional alluvial monitoring wells will be installed to further characterize and monitor pumps, ground-water flow and quality in alluvial materials at the 903 Pad, Mound, and East Trenches Areas. An unspecified number of additional bedrock monitoring wells will be completed in subcropping Arapahoe sandstone where it is encountered. All plume characterization wells will be installed, developed, and sampled as the first step of the investigation. Source characterization activities will be performed subsequently. This "step-approach" will facilitate early evaluation of the need for an Interim Measures/Interim Remedial Action to mitigate contaminant migration in ground water of the upper HSU before issuance of the draft RFI/RI report.

Nineteen surface water stations were established south of the 903 Pad and East Trenches Areas in the Woman Creek drainage during the 1986 and 1987 investigations, and 12 stations were established north of the Mound and East Trenches Areas in the South Walnut Creek drainage. One station has been deleted and four have been added to the sampling program. These 32 stations are being sampled during the monthly site-wide routine sampling program.

In order to assess the extent of plutonium and americium in surficial soils within Plant boundaries, pedologic soil samples will be collected from 122 grids over an 800 acre area to the southeast of the 903 Pad. To delineate the vertical distribution of plutonium and americium, 22 locations have been identified for soil test pit excavation for soil profile sampling. Additional studies have been planned to assess the mobility of plutonium in the soil/water environment and are described in Section 5.4, Surficial Soils.

A baseline risk assessment will be prepared for the 903 Pad, Mound, and East Trenches Areas as part of the Phase II RFI/RI to evaluate the potential threat to the public health and the environment in the absence of

remedial action This risk assessment will provide the basis for determining whether or not remedial action is necessary in the area and serve as the justification for performing remedial actions

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GLOSSARY OF ACRONYMS

<u>Acronym</u>	<u>Meaning</u>
ACL	Alternative Concentration Limit
AEC	United States Atomic Energy Commission
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Ambient Water Quality Criteria
BCFs	Bioconcentration Factors
C	carbon
CAA	Clean Air Act
CAD	Corrective Action Decision
CCl ₄	Carbon Tetrachloride
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CEARP	Comprehensive Environmental Assessment and Response Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Ci	Curies
CLP	Contract Laboratory Program
CFR	Code of Federal Regulations
CHCl ₃	Chloroform
cm	centimeter
cm/s	centimeters per second
CMS	Corrective Measures Study
CMS/FS	Corrective Measures Study/Feasibility Study
cpm	counts per minute
CRP	Community Relations Plan
CSU	Colorado State University
CWA	Clean Water Act
1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene
DCG	DOE-derived concentration guide
DNAPLs	Dense Nonaqueous-Phase Liquids
dpm/g	disintegrations per minute per gram
dpm/kg	disintegrations per minute per kilogram
DOE	United States Department of Energy
DOW	Division of Wildlife
DQO	Data Quality Objective
DRCOG	Denver Regional Council of Governments
EE	Environmental Evaluation
EEWP	Environmental Evaluation Work Plan
EIS	Environmental Impact Statement
EMAD	Environmental Monitoring and Assessment Division
EPA	United States Environmental Protection Agency
ER	Environmental Restoration Program
ERDA	Energy Research and Development Administration
FFACO	Federal Facility Agreement and Consent Order
FIDLER	Field Instrument for Detection of Low Energy Radiation
FR	Federal Register

GLOSSARY OF ACRONYMS (Continued)

FS	Feasibility Study
FSP	Field Sampling Plan
ft/ft	foot per foot
ft/yr	foot per year
g	gram
g/cm ³	grams per cubic centimeter
g/l	grams per liter
GFAA	Graphite Furnace Absorption Spectroscopy
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
GPM	Gallons Per Minute
GW	Ground Water
HASL	Health and Safety Laboratory, United States Atomic Energy Commission
HEAST	Health Effects Assessment Summary Tables
HSL	Hazardous Substance List
HSP	Health and Safety Plan
HSU	Hydrostratigraphic Unit
IHSS	Individual Hazardous Substance Site
IAG	Inter-Agency Agreement - the Federal Facility Agreement & Consent Order (FFACO)
IM/IRA	Interim Measures/Interim Remedial Action
IM/IRAP	Interim Measures/Interim Remedial Action Plan
IRIS	Integrated Risk Information System
KPA	kiloPascals
kg	kilograms
l	liter
LCL	Lower Confidence Level
m	meter
M	Molar
MATC	Maximum Allowable Tissue Concentrations
mCi/m ²	microCuries per square meter
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDA	Minimum Detectable Activity
mg	milligrams
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
ml	milliliters
mm	millimeters
msl	mean sea level
MT&E	Measuring and Test Equipment
NCP	National Contingency Plan
nm	nanometers
NPDES	National Pollutant Discharge Elimination System
OSWER	Office of Solid Waste and Emergency Response
OTD	Office of Technology Development
OU	Operable Unit
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PCE	Tetrachloroethene
PQL	Practical Quantitation Unit
pCi/g	picoCuries per gram
pCi/kg	picoCuries per kilogram

GLOSSARY OF ACRONYMS (Continued)

pCi/l	picoCuries per liter
pCi/m ³	picoCuries per cubic meter
PSZ	Perimeter Security Zone
Pu	Plutonium
QA	Quality Assurance
QAA	Quality Assurance Addendum
QA/QC	Quality Assurance/Quality Control
QAPJP	Quality Assurance Project Plan
RAAMP	Radioactive Ambient Air Monitoring Program
RAID	Superfund Risk Assessment Information Directory
RAGS-EEM	Risk Assessment Guidance for Superfund-Environmental Evaluation Manual
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act of 1976
RFD	Relative Percent Difference
RfD	Reference Dose
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFI/RIFS	RCRA Facility Investigation/Remedial Investigation Feasibility Study
RFP	Rocky Flats Plant
RI	Remedial Investigation
RIFS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPD	Relative Percent Difference
RPM	Revolutions per Minute
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SEAM	Superfund Exposure Assessment Manual
SED	Sediment Sampling Station
SID	South Interceptor Ditch
SITE	Superfund Innovative Technology Evaluation
SOP	Standard Operating Procedures
SPHEM	Superfund Public Health Evaluation Manual
SW	Surface Water Monitoring Station
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TBC	To Be Considered
1,1,1-TCA	1,1,1-trichloroethane
TCE	Trichloroethene
TCL	Target Compound List
TDR	Time Domain Reflectometry
TDS	Total Dissolved Solids
TLL	Total Long Lived Alpha
TSP	Treatability Studies Plan
UCL	Upper Confidence Level
WQCC	Colorado Water Quality Control Commission
μCi	microcuries
μCi/l	microcuries per liter
μg/kg	micrograms per kilogram
μg/l	micrograms per liter
μm	micrometer

INTRODUCTION

This document presents the alluvial work plan for the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Remedial Investigation (RFI/RI) of the 903 Pad, Mound, and East Trenches Areas [Operable Unit Number 2 (OU No 2)] at the Rocky Flats Plant, Jefferson County, Colorado. It addresses characterization of contaminant sources as well as the nature and extent of contamination in surficial soils, borehole materials, and ground water within the upper hydrostratigraphic unit (HSU). This work plan also presents the tasks that must be completed in the performance of the RCRA Corrective Measure Study/CERCLA Feasibility Study (CMS/FS). A comparable Phase II RFI/RI Work Plan (bedrock) has been completed which addresses characterization and the nature and extent of contamination in the bedrock and confined water bearing zones beneath the upper (alluvial) HSU (EG&G, 1991a). The data obtained during the "alluvial" and "bedrock" components of the RFI/RI field work will be combined and presented in a single RFI/RI report. This report will be the basis for the baseline risk assessment (included in the RFI/RI Report) and the CMS/FS.

This investigation is part of a comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at the Rocky Flats Plant. These investigations are pursuant to the U.S. Department of Energy (DOE) Environmental Restoration (ER) Program [formerly known as the Comprehensive Environmental Assessment and Response Program (CEARP)], a Compliance Agreement between DOE, the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH) dated July 31, 1986, and the Federal Facility Agreement and Consent Order (FFACO) [known as the Inter-Agency Agreement (IAG)]. The program developed by DOE, EPA, and CDH in response to the agreements addresses RCRA and CERCLA issues and has been integrated with the ER Program. In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study".

1.1 ENVIRONMENTAL RESTORATION PROGRAM

The ER Program is designed to investigate and clean up contaminated sites at DOE facilities. The ER Program is being implemented in five phases. Phase 1 (Installation Assessment) includes preliminary assessments and site inspections to assess potential environmental concerns. Phase 2 (Remedial Investigations) includes planning and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites, and evaluate potential contaminant migration pathways. Phase 3 (Feasibility Studies) evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified as needing correction in Phase 2. Phase 4 (Remedial Design/Remedial Action) includes design and

implementation of site-specific remedial actions selected on the basis of Phase 3 feasibility studies Phase 5 (Compliance and Verification) implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under Phase 4 Phase 1 has already been completed at Rocky Flats Plant (DOE, 1986), and Phases 2, 3, and 4 are currently in progress for OU No 2

Phase 2 activities at OU No 2 include a Phase I RI and subsequent plans for Phase II investigations An initial (Phase I) field program was completed at the 903 Pad, Mound, and East Trenches Areas in 1987, and a draft Phase I RI report was submitted to EPA and CDH in December 1987 (Rockwell International, 1987a) Based on results of that investigation and regulatory agency comments, planning for a Phase II investigation began in 1988 A draft Phase II RI Work Plan was submitted to EPA and CDH in June 1988 (Rockwell International, 1988a), which included plans for further characterization of sources as well as alluvial and bedrock ground-water flow systems Pursuant to the IAG, a second draft Phase II RI/FS work plan was submitted to EPA and CDH in December 1989 (Rockwell International, 1989a) which addressed characterization of sources and the uppermost aquifer (surficial materials and hydraulically connected sandstones) Based on EPA and CDH comments on the draft document, a final Phase II RFI/RI Work Plan for OU No 2 was submitted to EPA and CDH on 12 April 1990 (EG&G, 1990a) This February 1991 document is Revision 1 of the Final Phase II RFI/RI Work Plan (alluvial) and incorporates agency comments on the 12 April 1990 submittal Although not required by the IAG, Revision 1 was prepared so that final agency comments are reflected in a single document prior to implementation of the Phase II (alluvial) scope of work This better assures that the RFI/RI and CMS/FS are conducted in accordance with a plan to which all parties are in agreement It is noted that this plan has also been modified for reasons not associated with specific agencies comments These changes have been made to "update" the plan with respect to the current understanding of the site, other OU study activities that impact OU No 2, and regulatory issues Major changes are as follows

- Revised geological characterization based on the on-going seismic reflection study (Section 2 2 1)
- Addition of a concise site conceptual model (Section 2 4)
- Elaboration on data quality objectives (Section 3 0)
- Discussion of all Rocky Flats Plant treatability study programs (Section 4 1 7)
- Addition of seven plume characterization wells between the OU and site boundary because of the recent occurrence of contamination in this location (Section 5 2 1 3)
- Elimination of surface water station sampling (except seeps) because the activity is covered by OU Nos 5 and 6 as well as a site-wide surface water characterization program
- Addition of a more extensive surface soil sampling program to assess the mobility of plutonium in the soil/water environment (Section 5 4 and Attachment 1 0)

- Addition of a detailed environmental evaluation work plan (EEWP) (Section 6 0)
- Elaboration and modification to the discussion of applicable or relevant and appropriate requirements (ARARs) (Section 7 0)

Results of the Phase I RI indicate that a depositionally complex bedrock hydrogeologic system exists beneath the 903 Pad, Mound, and East Trenches Areas. A draft Geologic Characterization Report for the Rocky Flats Plant (EG&G, 1990b) has been prepared based on re-evaluation of log data and other geologic information. That report contains a revised working model of the bedrock geology. In order to further characterize the location, extent, and orientation of sandstones, and bedrock facies and stratigraphic relationships, high resolution seismic reflection programs were performed at OU No. 2 (Rockwell International, 1989b and EG&G, 1990c). A separate Phase II RFI/RI Work Plan (bedrock) has been prepared presenting the information provided in the geologic characterization report with the results of the seismic survey to further refine the working model of the bedrock geology.

ER Program Phase 3 and 4 activity to date at OU No. 2 consists of an Interim Measure/Interim Remedial Action Plan (IM/IRAP) for contaminated surface water. A draft IM/IRAP was submitted to EPA and CDH on 12 June 1990 (EG&G, 1990d), and a Draft Final IM/IRAP was submitted to the agencies on 26 September 1990 (EG&G, 1990e). Formal responses to agency comments on the draft IM/IRAP were also submitted with the draft final plan. The Final IM/IRAP, which incorporated public and agency comments on previous drafts, was submitted to CDH and EPA on 11 January 1991 (EG&G, 1991b). Due to public comments, this Final IM/IRAP, unlike the previous drafts, focuses only on South Walnut Creek. A second IM/IRAP for Woman Creek is in preparation.

1 2 WORK PLAN OVERVIEW

This Phase II RFI/RI Work Plan for the 903 Pad, Mound, and East Trenches Areas presents results of the Phase I RI, defines data quality objectives and data needs based on that investigation, specifies Remedial Investigation/Feasibility Studies (RI/FS) tasks, and presents a Field Sampling Plan (FSP). This section (1 0 Introduction) presents site locations and descriptions, and Section 2 0 presents results of the Phase I RI. Included in Section 2 0 are Phase I characterization results for site geology and hydrology as well as the nature and extent of contamination in soils, ground water, surface water, and sediments. Section 3 0 discusses data needs and data quality objectives (DQOs) for the Phase II RFI/RI investigation. Section 4 0 specifies RI/FS tasks to be performed, and Section 5 0 presents the FSP to meet RI/FS objectives. The EEWP for OU No. 2 is presented in Section 6 0, and the ARARs are presented in Section 7 0. The proposed schedule for conducting the RFI/RI is presented in Section 8 0, and the site-specific Quality Assurance Addendum (QAA) is contained in Section 9 0.

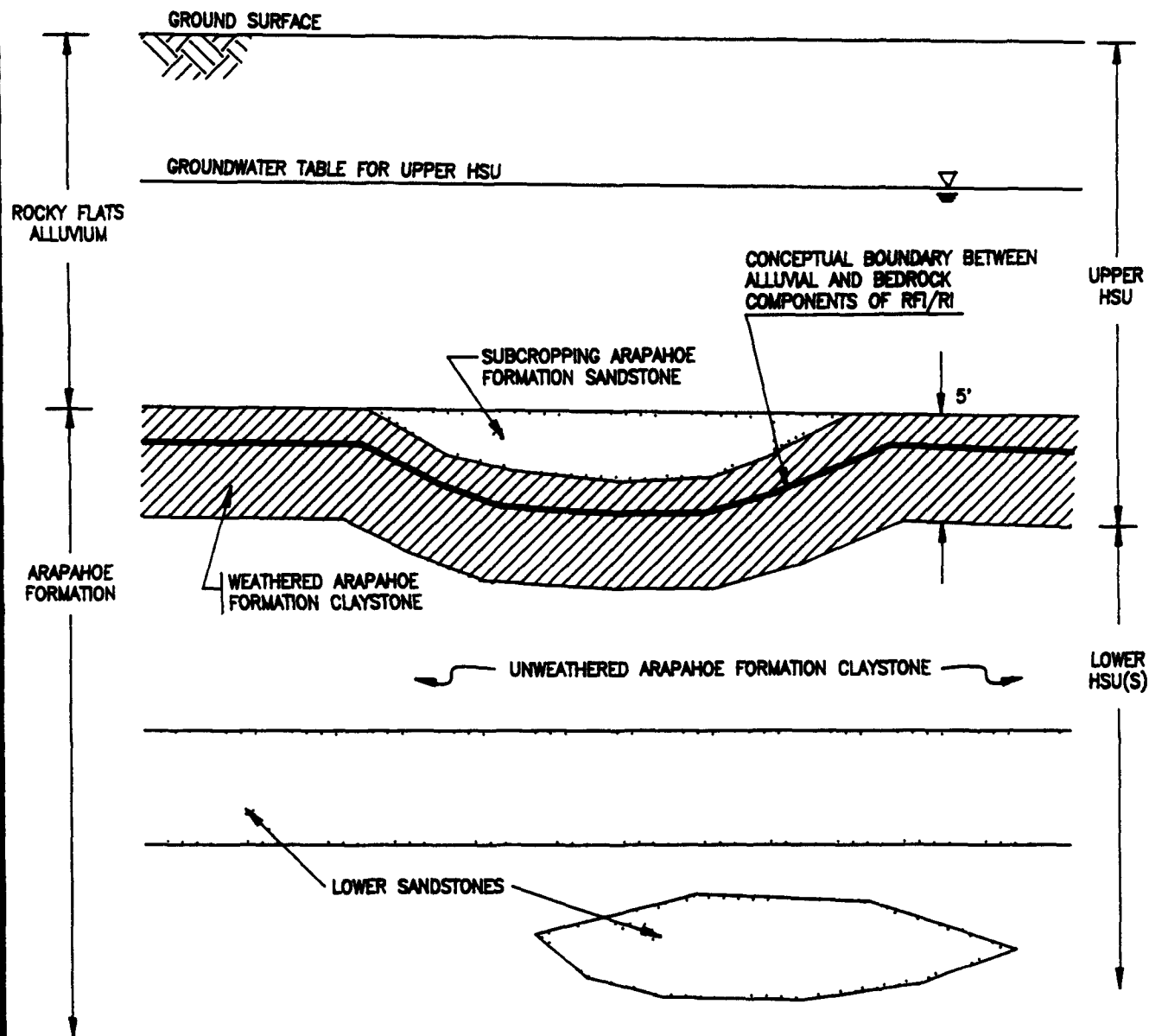
The field sampling plan for surficial soil sampling and for conducting the Environmental Evaluation (EE) is presented in Attachments 1 0 through 4 0 Attachment 5 0 contains the responses to EPA and CDH comments on the 12 April 1990 submittal of the OU No 2 Work Plan Appendices A through E contain available data pertaining to OU No 2 through second quarter 1989 (same data set that was used in the December 1989 submittal) At this time, only a portion of the data have been validated, and these data are identified in the appendices by a qualifier adjacent to each datum The qualifier "V" means the datum is valid, "A" means the datum is acceptable with qualifications [breach of quality assurance (QA)], and "R" means the datum is rejected Rejected data either did not conform to the significant aspects of Quality Assurance/Quality Control (QA/QC) procedures identified in the applicable ER Program QA/QC Plan (Rockwell International, 1989c), or there is insufficient documentation to demonstrate conformance with these procedures These data, at best, can only be considered qualitative measures of the analyte concentrations

Figure 1-1 depicts the conceptual boundary between the alluvial (upper HSU) and bedrock (lower HSU) components of the RFI/RI The upper HSU is defined as alluvial deposits and interconnected sandstones, and the lower HSU includes deeper bedrock units Subcropping sandstones are hydraulically connected with the overlying alluvium and thus are part of the upper HSU For the purpose of developing work plan scopes, the boundary between the upper and lower HSUs is considered to occur five feet below the upper surface of the uppermost claystone There will be some overlap between the two components of the RFI/RI However, characterization of the alluvial material and subcropping sandstones will be completed by the alluvial RFI/RI Overlap will occur in the weathered claystones and where lower sandstones subcrop

1 3 BACKGROUND AND PHYSICAL SETTING

1 3 1 Background

The Rocky Flats Plant is a government-owned, contractor-operated facility, which is part of the nationwide nuclear weapons production complex The Plant was operated for the U S Atomic Energy Commission (AEC) from its inception in 1951 until the AEC was dissolved in January 1975 At that time, responsibility for the Plant was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the DOE in 1977 Dow Chemical U S A , an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975 Rockwell International was the prime contractor responsible for operating the Rocky Flats Plant from July 1, 1975, until December 31, 1989 EG&G, Rocky Flats, Inc , became the prime contractor at the Rocky Flats Plant on January 1, 1990, and currently operates the Plant



NOTE HSU = HYDROSTRATIGRAPHIC UNIT

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

CONCEPTUAL BOUNDARY BETWEEN
ALLUVIAL AND BEDROCK COMPONENTS
OF RFI/RI

FIGURE 1-1

February, 1991

1 3 1 1 Plant Operations

The primary mission of the Rocky Flats Plant is to fabricate nuclear weapon components from plutonium, uranium, and other non-radioactive metals (principally beryllium and stainless steel) Parts made at the Plant are shipped elsewhere for assembly In addition, the Plant reprocesses components after they are removed from obsolete weapons for recovery of plutonium

Both radioactive and nonradioactive wastes are generated in the production process Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility However, both storage and disposal of hazardous, radioactive, and radioactive mixed wastes occurred on site in the past Preliminary assessments under the ER Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination

1 3 1 2 Previous Investigations

Various studies have been conducted at the Rocky Flats facility to characterize environmental media and to assess the extent of radiological and chemical contaminant releases to the environment The investigations performed prior to 1986 are summarized in Rockwell International (1986a) and include

- Detailed descriptions of the regional geology (Malde, 1955, Spencer, 1961, Scott, 1960, 1963, 1970, 1972 and 1975, Van Horn, 1972 and 1976, DOE, 1980, Dames and Moore, 1981, and Robson, et al , 1981a and 1981b)
- Several drilling programs beginning in 1960 that resulted in the construction of approximately 60 monitor wells by 1982
- An investigation of surface and ground-water flow systems by the U S Geological Survey (Hurr, 1976)
- Environmental, ecological, and public health studies which culminated in an environmental impact statement (DOE, 1980)
- A summary report on ground-water hydrology using data from 1960 to 1985 (Hydro-Search, Inc , 1985)
- A preliminary electromagnetic survey of the Plant perimeter (Hydro-Search, Inc , 1986)
- A soil gas survey of the Plant perimeter and buffer zone (Tracer Research, Inc , 1986)
- Routine environmental monitoring programs addressing air, surface water, ground water, and soils These programs are summarized in the annual environmental monitoring reports (Rockwell International 1975 through 1983a, 1984, 1985, and 1986b) Additional information on routine environmental programs is also presented in post-1986 annual environmental monitoring reports (Rockwell International, 1987b and 1989d, and EG&G, 1990f)

In 1986, two major investigations were completed at the Plant. The first was the ER Program Phase 1 installation assessment (DOE, 1986) which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. A number of sites were identified that could potentially have adverse impacts on the environment. These sites were designated Solid Waste Management Units (SWMUs) by Rockwell International (1987c) and were divided into three categories:

- 1) Hazardous waste management units that will continue to operate and need a RCRA operating permit
- 2) Hazardous waste management units that will be closed under RCRA interim status
- 3) Inactive waste management units that will be investigated and cleaned up under Section 3004(u) of RCRA or CERCLA

The IAG redefines the SWMUs within the second and third categories as Individual Hazardous Substance Sites (IHSS). The term is used hereinafter, however, no RCRA or CERCLA regulatory distinction in the use of the terms "site", "unit", or "IHSS" is intended in this document.

The second major investigation completed at the Plant in 1986 involved a hydrogeologic and hydrochemical characterization of the entire Plant site. Plans for this study were presented in Rockwell International (1986c and 1986d), and study results were reported in Rockwell International (1986e). Investigation results indicated four areas to be significant contributors to environmental contamination, with each area containing several sites. The areas are the 881 Hillside Area, the 903 Pad Area, the Mound Area, and the East Trenches Area.

Due to their proximity, the 903 Pad, Mound, and East Trenches Areas were grouped together and designated OU No. 2. A Phase I RI of OU No. 2 was completed in December 1987 (Rockwell International, 1987a). Since that time, DOE, in conjunction with EPA and CDH, has been formulating plans for the Phase II RFI/RI as discussed in Section 1.1.

Two other Plant-wide studies have been conducted since the Phase I RI which affect further RFI/RI activities at OU No. 2. First, a draft Geologic Characterization Report for the Rocky Flats Plant (EG&G, 1990b) was completed in January 1990 based on re-evaluation of log data and other geologic information. This study supersedes all previous geologic investigations with the exception of Hurr (1976). The second study of note was the draft Background Geochemical Characterization Report (EG&G, 1990g). This revised report summarizes background data for ground water, surface water, sediments, and geologic materials and identifies preliminary statistical boundaries of background variability.

1 3 1 3 Current Investigations and Studies

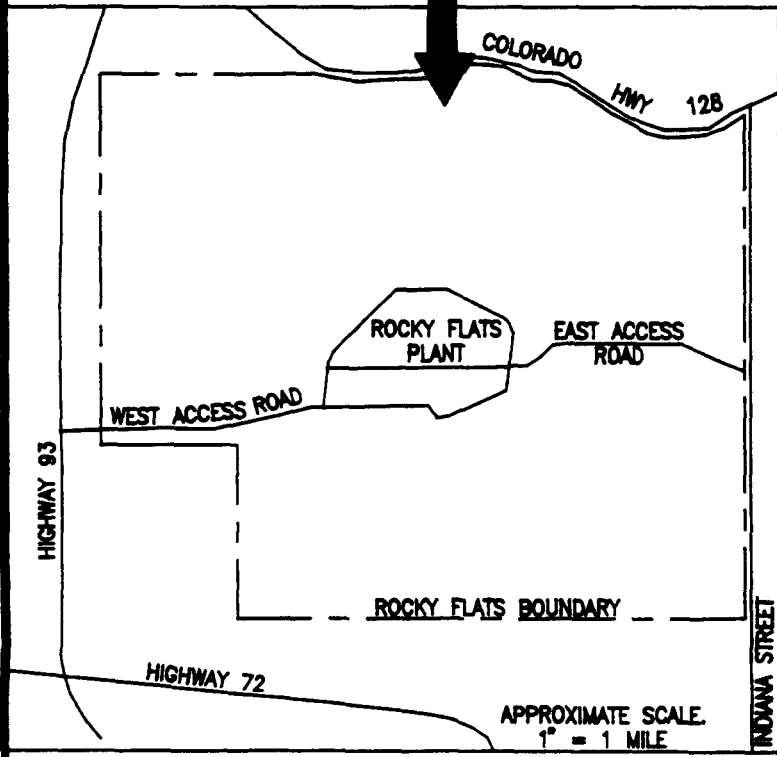
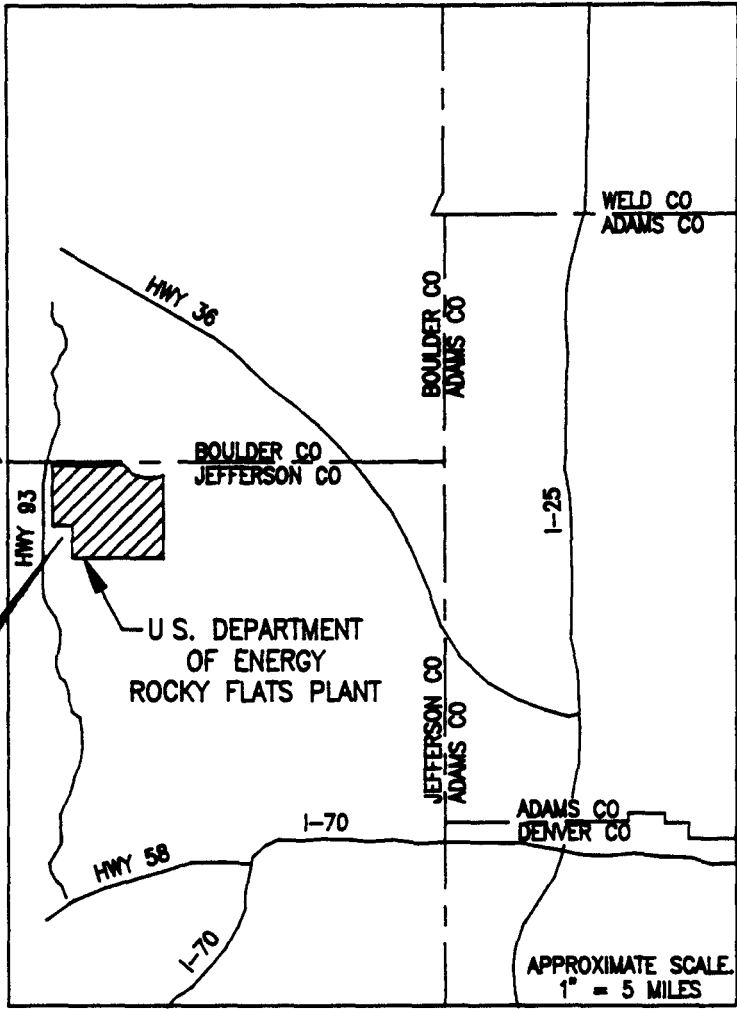
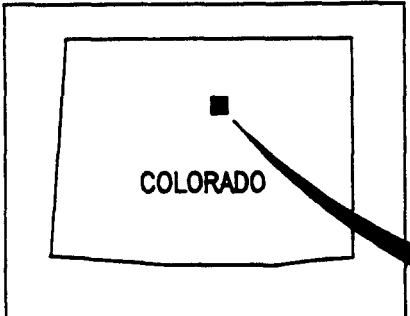
OU No 2 is located between three other operable units where current studies are likely to provide data that will support the determination of the nature and extent of contamination at OU No 2. These operable units are to the southwest, OU No 1 (881 Hillside Area), to the south OU No 5 (Woman Creek), and to the north, OU No 6 (Walnut Creek). The RFI/RI Phase III Work Plan for OU No 1 was conditionally approved by the regulatory agencies, and field investigations are scheduled to begin in April 1991. The draft RFI/RI Report for OU No 1 will be submitted in July 1992, well in advance of the OU No 2 RFI/RI Report (draft report scheduled to be submitted in March 1993). This will permit full utilization of the OU No 1 findings for the OU No 2 RFI/RI. The OUs 5 and 6 RFI/RI Work Plans are scheduled to be submitted to the regulatory agencies in April 1991, and the RFI/RI Reports will be submitted in late 1993. This will permit only partial utilization of data collected for these OUs.

In addition to these adjacent RFI/RIs, two interim measures/interim remedial actions (IM/IRAs) for contaminated surface water at OU No 2 will be conducted during the course of the OU No 2 RFI/RI. These IM/IRAs will provide valuable data on the treatability of water contaminated with organics and radionuclides which will support the detailed evaluation of alternatives for the OU No 2 CMS/FS. There is also a site-wide routine sampling program being conducted at Rocky Flats. Surface water stations around the Plant are being sampled monthly for site-wide characterization of surface waters.

Lastly, the IAG site-wide activities will augment the RFI/RI and CMS/FS for OU No 2. In particular, the site-wide treatability studies will support the detailed evaluation of alternatives for the OU No 2 CMS/FS (see Section 4.1.7 for additional information regarding treatability studies activities), and the Historical Release Report may provide additional information on the nature of the wastes disposed at OU No 2. The draft Historical Release Report is scheduled to be submitted to the regulatory agencies in January 1992.

1 3 2 Physical Setting

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-2). Other surrounding cities include Boulder, Westminster, and Arvada, which are located less than ten miles to the northwest, east, and southeast, respectively. The Plant consists of approximately 6,550 acres of federally owned land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the Plant security area of approximately 400 acres. The security area is surrounded by a buffer zone of approximately 6,150 acres (Figure 1-3).



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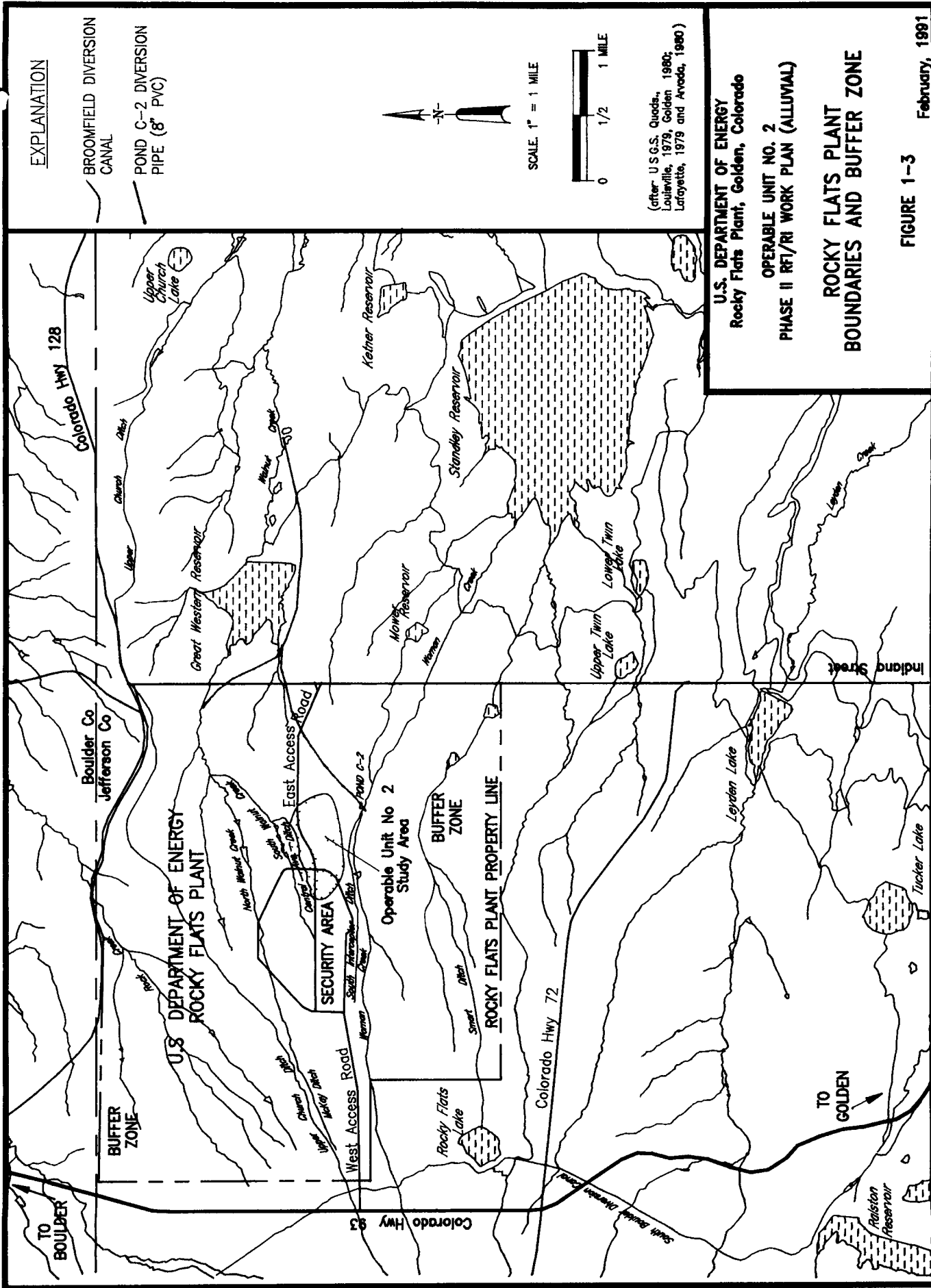
OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

GENERAL LOCATION OF
ROCKY FLATS PLANT

FIGURE 1-2

R33058.PJ-012991

R33059 PJ-022091



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Rocky Flats Plant, Golden, Colorado**

**OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)**

**ROCKY FLATS PLANT
BOUNDARIES AND BUFFER ZONE**

FIGURE 1-3 February, 1991

1 3.2 1 Topography

The natural environment of the Plant and vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. The Plant is directly east of the north-south trending Front Range and is located about 16 miles east of the Continental Divide. Rocky Flats Plant is located on a broad, eastward sloping plain of coalescing alluvial fans developed along the Front Range at an elevation of approximately 6,000 feet above mean sea level (msl). The fans extend about five miles in an eastward direction from their origin at Coal Creek Canyon and terminate on the east at a break in slope to low rolling hills. The operational area at the Plant is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek).

1 3.2.2 Surface Water Hydrology

Three intermittent streams drain the Rocky Flats Plant with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 1-3). Rock Creek drains the northwestern corner of the Plant and flows northeast through the buffer zone to its off-site confluence with Coal Creek. An east-west trending interfluvium separates the Walnut and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the Plant security area. These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir which is approximately one mile east of the confluence. This flow is, however, routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield. Woman Creek drains the southern Rocky Flats Plant buffer zone flowing eastward to Standley Reservoir. The South Interceptor Ditch (SID) lies between the Plant and Woman Creek. The SID collects runoff from the southern Plant security area and diverts it to Pond C-2, where it is treated and monitored in accordance with the Plant National Pollutant Discharge Elimination System (NPDES) permit. Treated water from Pond C-2 is then diverted to the Walnut Creek watershed where it is released to the Broomfield Diversion Canal.

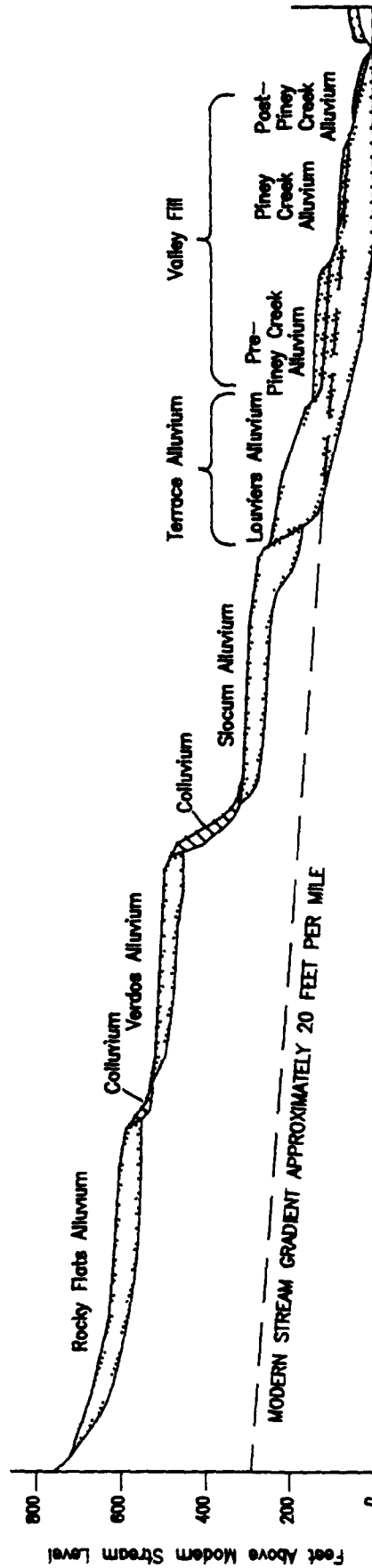
1 3.2.3 Regional and Local Hydrogeology

Geologic units beneath the Rocky Flats Plant consist of unconsolidated surficial units [Rocky Flats Alluvium, various terrace alluvia, valley fill alluvium, and colluvium (Figure 1-4)], underlain by Cretaceous bedrock [Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone (Figure 1-5)]. Figure 1-6 presents a generalized stratigraphic section of the Denver Basin bedrock, and Figure 1-7 shows a stratigraphic section for the Rocky Flats Plant. Ground water occurs under unconfined conditions in both surficial and shallow bedrock units. In addition, confined ground-water flow occurs in deeper bedrock sandstones.

EAST

ROCKY FLATS PLANT SITE

WEST



NOT TO SCALE

(after Scott, 1960)

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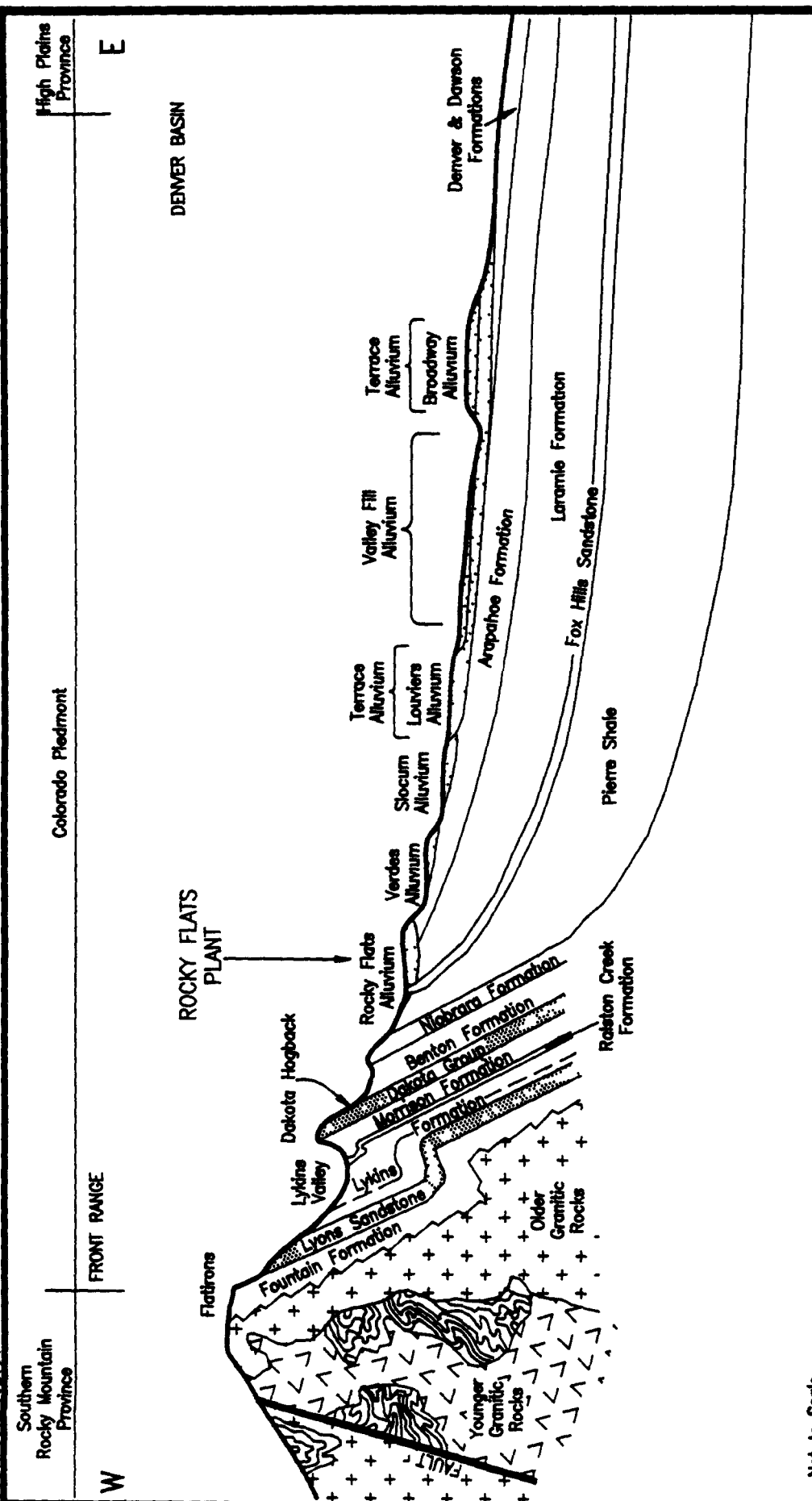
OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

EROSIONAL SURFACES AND ALLUVIAL
DEPOSITS EAST OF THE FRONT RANGE
COLORADO

FIGURE 1-4

February, 1991

R33081.PCW-032191



(after Boulder County Planning Commission, 1983 and Scott, 1960)

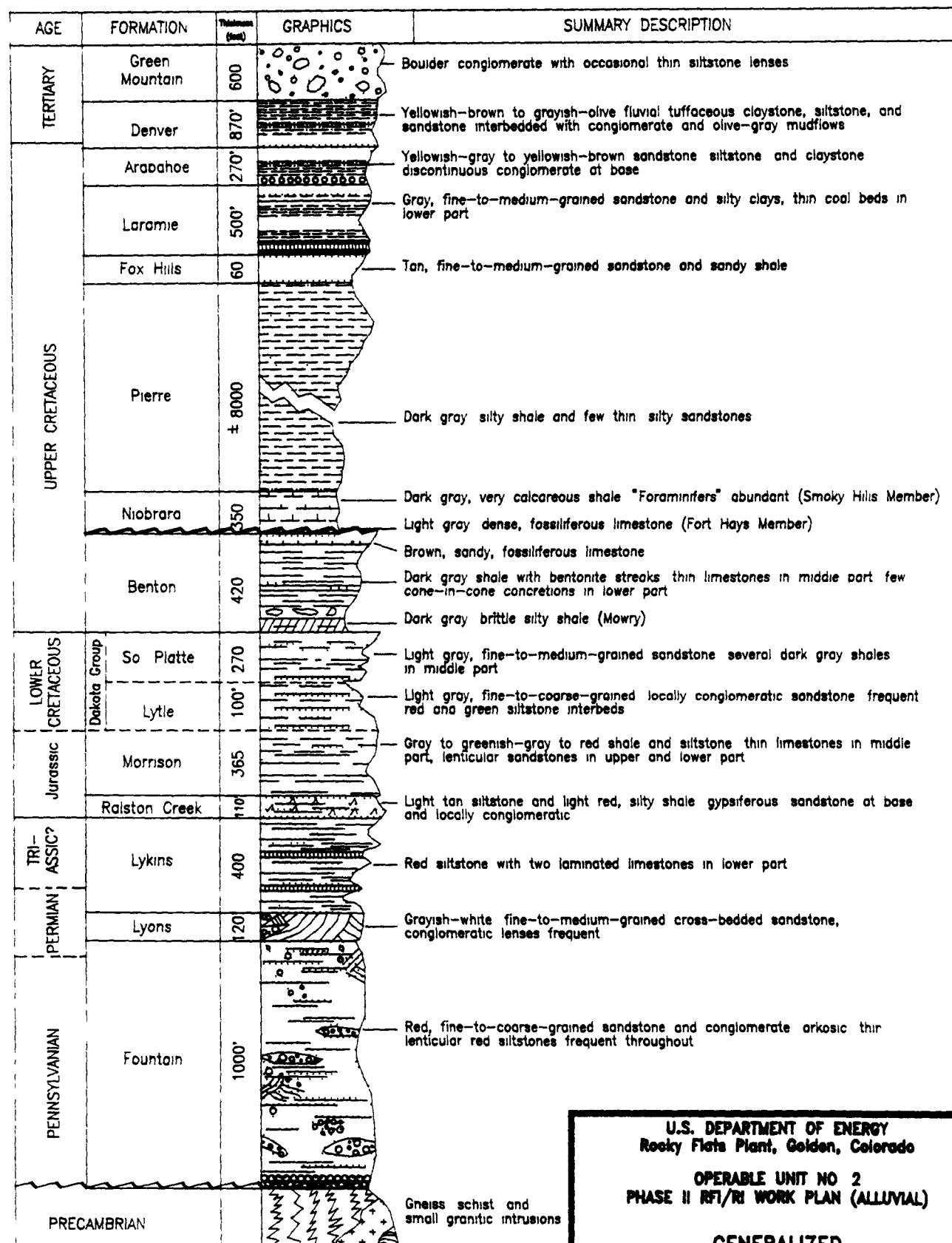
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OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

GENERALIZED EAST-WEST
CROSS SECTION
FRONT RANGE TO DENVER BASIN

FIGURE 1-5

February, 1991

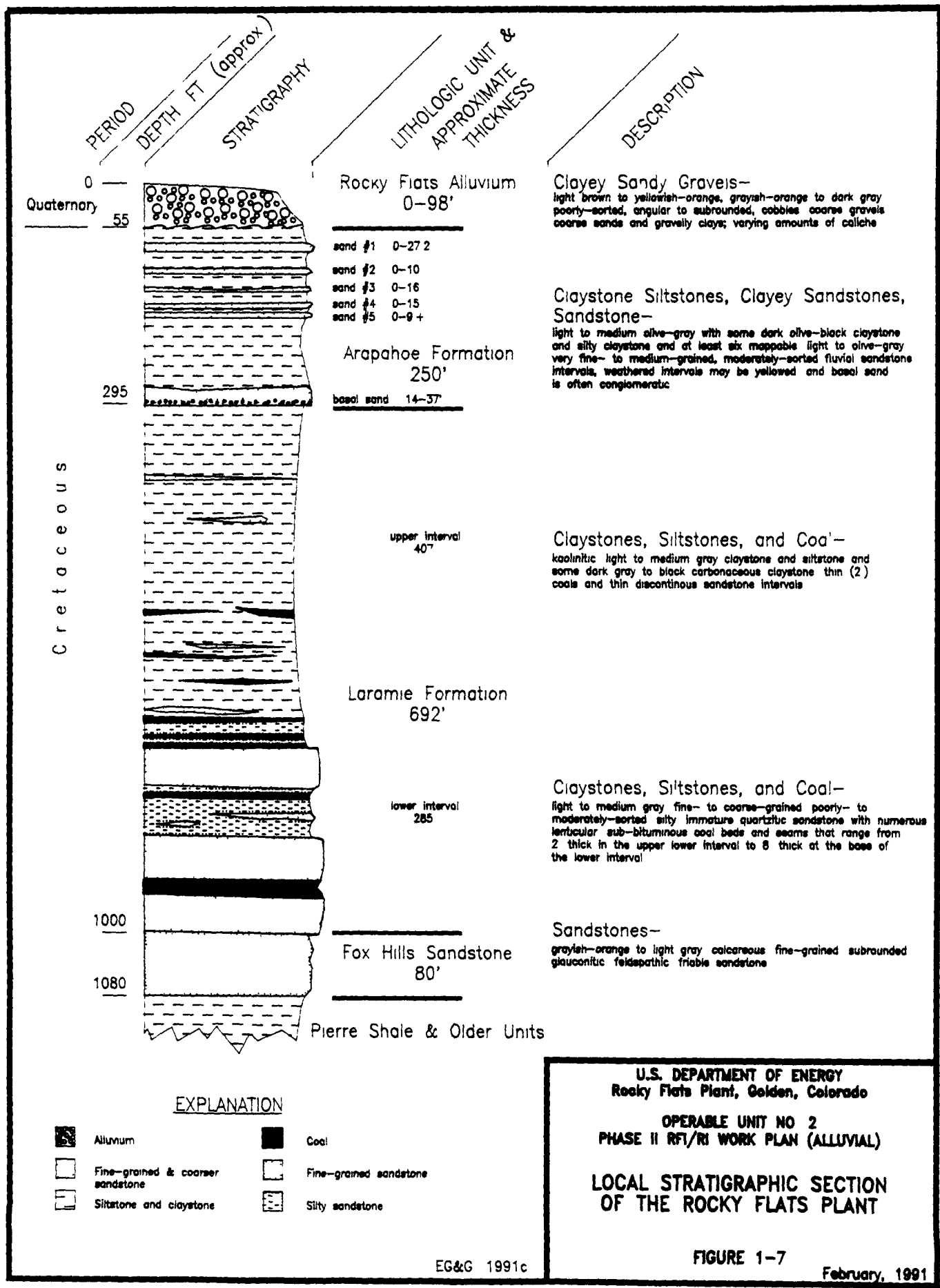


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

GENERALIZED
STRATIGRAPHIC SECTION
FOR DENVER BASIN

FIGURE 1-6

February, 1991



R33054B PUCW-0322191

Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at the Rocky Flats Plant (Scott, 1965) The Rocky Flats Alluvium is a series of coalescing alluvial fans deposited by braided streams (Hurr, 1976) It consists of a topsoil layer underlain by up to 100 feet of varying amounts of silt, clay, sand, and gravel The erosional surface (pediment) on which the alluvium was deposited slopes gently eastward truncating the Fox Hills Sandstone, the Laramie Formation, and the Arapahoe Formation at the Rocky Flats Plant

After deposition of the Rocky Flats Alluvium, eastward flowing streams began dissecting the deposit by headward erosion and lateral planation All of the alluvium was removed by erosion in the Woman Creek drainage south of OU No 2 and in the South Walnut Creek drainage to the north The result is a terrace of Rocky Flats Alluvium extending eastward from the Plant between the two drainages

Unconfined ground-water flow occurs in the Rocky Flats Alluvium, which is relatively permeable Recharge to the alluvium is from precipitation, snowmelt, and water losses from ditches, streams, and ponds that are cut into the alluvium General water movement in the Rocky Flats Alluvium is from west to east, and toward the drainages Ground-water flow is also controlled by pediment drainages in the top of bedrock Ground-water levels in the Rocky Flats Alluvium rise in response to recharge during the spring and decline during the remainder of the year Discharge from the alluvium occurs at seeps in the colluvium that covers the contact between the alluvium and bedrock along the edges of the valleys Most seeps flow intermittently The Rocky Flats Alluvium thins due to erosion east of the Plant boundary and does not directly supply water to wells located downgradient of Rocky Flats Plant

Other Alluvial Deposits

Various other alluvial deposits occur topographically below the Rocky Flats Alluvium in the Plant drainages Colluvium (slope wash) mantles the valley side slopes between the Rocky Flats Alluvium and the valley bottoms In addition, remnants of younger terrace deposits including the Verdos, Slocum, and Louviers Alluvia occur occasionally along the valley side slopes Recent valley fill alluvium occurs in the active stream channels

Unconfined ground-water flow occurs in these surficial units Recharge is from precipitation, percolation from streams during periods of surface water runoff, and by seeps discharging from the Rocky Flats Alluvium Discharge is by evapotranspiration and by seepage into other geologic formations and streams The direction of ground-water flow is generally downslope through colluvial materials and then along the course of the

stream in valley fill materials. During periods of high surface water flow, water is lost to bank storage in the valley fill alluvium and returns to the stream after the runoff subsides.

Arapahoe Formation

The Arapahoe Formation underlies surficial materials beneath most of the Plant except beneath the western portions of the Plant. From approximately the middle of the west buffer zone and west almost to Highway 93, the Laramie Formation unconformably underlies the Rocky Flats Alluvium. The Arapahoe Formation is a fluvial deposit composed of overbank and channel deposits. It consists predominantly of claystones and siltstones, with some silty sandstones beneath the central and eastern portions of the Plant. Total formation thickness varies up to 270 feet (Robson, et al., 1981a), and the unit is nearly flat lying beneath the Plant (less than two degree dip) (EG&G, 1990b and 1990c). The sandstone bodies within the claystone are composed of very fine-grained sand and silt, and their hydraulic conductivity is equivalent to or less than that of the overlying Rocky Flats Alluvium. Geologic characterization of the Arapahoe Formation beneath Rocky Flats indicates sandstones occur in stream channel-shaped structures (EG&G, 1990b). The Arapahoe Formation beneath the Plant contains more clay and silt than typically described for other areas within the Denver Basin.

The Arapahoe Formation is recharged by ground water from overlying surficial deposits and infiltration from streams. The main recharge areas are under the Rocky Flats Alluvium, although some recharge from the colluvium and valley fill alluvium likely occurs along the stream valleys. Recharge is greatest during the spring and early summer when rainfall and stream flow are at a maximum and water levels in the Rocky Flats Alluvium are high. Ground-water movement in the Arapahoe Formation is generally toward the east, although flow within individual sandstones is controlled locally by the channel geometries. Regionally, ground-water flow in the Arapahoe Formation is toward the South Platte River in the center of the Denver Basin (Robson, et al., 1981a).

Laramie Formation and Fox Hills Sandstone

The Laramie Formation conformably underlies the Arapahoe Formation and is composed of two units: a thick upper unit composed predominantly of claystone and a lower unit which contains coal and sandstone. The upper Laramie Formation is greater than 700 feet thick and is of very low hydraulic conductivity; therefore, the U.S. Geological Survey (Hurr, 1976) concludes that Plant operations will not impact any units below the upper claystone unit of the Laramie Formation.

The lower sandstone unit of the Laramie Formation and the underlying Fox Hills Sandstone comprise a regionally important aquifer in the Denver Basin known as the Laramie-Fox Hills Aquifer (Robson, 1983). Near the center of the basin, the aquifer thickness ranges from 200 to 300 feet. These units subcrop west of the Plant and can be seen in clay pits excavated through the Rocky Flats Alluvium. The steeply dipping beds of

these units west of the Plant (approximately 50°) quickly flatten to the east (less than 2° dip) (EG&G 1990b and 1990c) Recharge to the aquifer occurs along the rather limited outcrop area exposed to surface water flow and leakage along the Front Range (Robson, et al , 1981b)

1 3 2 4 Meteorology

The area surrounding the Rocky Flats Plant has a semiarid climate characteristic of much of the central Rocky Mountain region Approximately forty percent of the 15-inch annual precipitation falls during the spring season, much of it as wet snow Thunderstorms (June to August) account for an additional 30 percent of the annual precipitation Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively Snowfall averages 85 inches per year, falling from October through May (DOE, 1980)

Special attention has been focused on dispersion meteorology surrounding the Plant due to the remote possibility that significant atmospheric releases might affect the Denver metropolitan area Studies of air flow and dispersion characteristics (e g , Hodgins, 1983 and 1984) indicate that drainage flows (winds coming down from the mountains to the west), turn and move toward the north and northeast along the South Platte River valley and pass to the west and north of Brighton, Colorado (DOE, 1980)

1 3 2 5 Surrounding Land Use and Population Density

The Rocky Flats Plant is located in a rural area Approximately 50 percent of the area within 10 miles of the Rocky Flats Plant is in Jefferson County The remainder is located in Boulder County (40 percent) and Adams County (10 percent) According to the 1973 Colorado Land Use Map, 75 percent of this land was unused or was used for agriculture Since that time, portions of this land have been converted to housing, with several new housing subdivisions being started within a few miles of the buffer zone

A recent demographic study shows that approximately 2.2 million people live within 50 miles of the Rocky Flats Plant in 1989 (DOE, 1990a) Approximately 9,100 people lived within five miles of the Plant in 1989 (DOE 1990a) The most populous sector was to the southeast, toward the center of Denver Recent population estimates, registered by the Denver Regional Council of Governments (DRCOG), for the eight-county Denver metro region have shown distinct patterns of growth between the first and second halves of the 1980s Between 1980 and 1985, the population of the eight-county region increased by 197,890, a 2.4 percent annual growth rate Between 1985 and 1989 a population gain of 71,575 was recorded, representing a 1.0 percent annual increase (the national average) The 1989 population showed an increase of 2,225 (or 0.1 percent) from the same date in 1988 (DRCOG, 1989)

There are eight public schools within six miles of the Rocky Flats Plant. The nearest educational facility is the Witt Elementary School, which is approximately 2.7 miles east of the Plant buffer zone. The closest hospital is Centennial Peaks Hospital located approximately seven miles northeast. The closest park and recreational area is the Standley Lake area, which is approximately five miles southeast of the Plant. Boating, picnicking, and limited overnight camping are permitted. Several other small parks exist in communities within ten miles. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres of general camping and outdoor recreation. Other national and state parks are located in the mountains west of the Rocky Flats Plant, but all are more than 15 miles away.

Some of the land adjacent to the Plant is zoned for industrial development. Industrial facilities within five miles include the TOSCO laboratory (40-acre site located two miles south), the Great Western Inorganics Plant (two miles south), the Frontier Forest Products yard (two miles south), the Idealite Lightweight Aggregate Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (990-acre site located 4.8 miles northeast).

Several ranches are located within 10 miles of the Plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses. According to the 1987 Colorado Agricultural Statistics, 20,758 acres of crops were planted in Jefferson County (total land area of approximately 475,000 acres) and 68,760 acres of crops were planted in Boulder County (total land area of 405,760 acres). Crops consisted of winter wheat, corn, barley, dry beans, sugar beets, hay, and oats. Livestock consisted of 5,314 head of cattle, 113 hogs, and 346 sheep in Jefferson County, and 19,578 head of cattle, 2,216 hogs, and 12,133 sheep in Boulder County (Post, 1989).

1.3.2.6 Ecology

A variety of vegetation thrives within the Plant boundary. Included are species of flora representative of tall grass prairie, short grass plains, lower montane, and foothill ravine regions. None of these vegetative species are on the endangered species list. It is evident that the vegetative cover along the Front Range of the Rocky Mountains has been radically altered by human activities such as burning, timber cutting, road building, and overgrazing for many years. Since the acquisition of the Rocky Flats Plant property, vegetative recovery has occurred as evidenced by the presence of disturbance-sensitive grass species such as big bluestem (*Andropogon gerardii*) and sideoats grama (*Bouteloua curtipendula*). No vegetative stresses attributable to hazardous waste contamination have been identified (DOE, 1980).

The animal life inhabiting the Rocky Flats Plant and its buffer zone consists of species associated with western prairie regions. The most common large mammal is the mule deer (*Odocoileus Lemionus*), with an estimated 100 to 125 permanent residents. There are a number of small carnivores, such as the coyote (*Canis latrans*),

red fox (*Vulpes fulva*), striped skunk (*Mephitis mephitis*), and long-tailed weasel (*Mustela frenata*) A profusion of small herbivores consisting of species such as the pocket gopher (*Thomomys* sp), white-tailed jackrabbit (*Lepus townsendii*), and the meadow vole (*Microtus pennsylvanicus*) can be found throughout the Plant and buffer zone (DOE, 1980)

Commonly observed birds include western meadowlarks (*Sturnella neglecta*), horned larks (*Eremophila alpestris*), mourning doves (*Zenaidura macroura*), and vesper sparrow (*Pooecetes gramineus*) A variety of shore birds such as killdeer (*Charadrius vociferus*), and red-winged black birds (*Agelaius phoeniceus*) are seen in areas adjacent to ponds Mallard ducks (*Anas platyrhynchos*) as well as other species of (*Anas* sp) frequently nest and rear young on several of the ponds Common birds of prey in the area include marsh hawks (*Circus cyaneus*), red-tailed hawks (*Buteo jamaicensis*), ferruginous hawks (*Buteo regalis*), rough-legged hawks (*Buteo lagopus*), and great horned owls (*Bubo virginianus*) (DOE, 1980)

Bull snakes (*Pituophis melanoleucus*) and rattlesnakes (*Crotalus* sp) are the most frequently observed reptiles Eastern yellow-bellied racers (*Coluber constrictor*) have also been seen The eastern short-horned lizard (*Phrynosoma douglassi brevirostre*) has been reported on the site, but these and other lizards are not commonly observed The western painted turtle (*Chrysemys picta*) and the western plains garter snake (*Thamnophis radix*) are found in and around many of the ponds (DOE, 1980)

The bald eagle and the black-footed ferret are the two endangered species which were identified as potentially present at Rocky Flats Plant by the U S Fish and Wildlife Service Bald eagles are occasional visitors to the area primarily during migration times However, eagle sightings are rare and little suitable habitat exists at the Plant No bald eagle nests have been found on the Plant site Prairie dogs provide the food source and habitat for black-footed ferrets Since there are no prairie dog towns in or near the 903 Pad, Mound and East Trenches Areas, ferrets probably do not exist at OU No 2 Subsequent to a field visit on June 15, 1988, the U S Fish and Wildlife Service has concurred with these findings (Rockwell International, 1988b)

1 4 SITE LOCATIONS AND DESCRIPTIONS

This RFI/RI Work Plan addresses the 903 Pad, Mound, and East Trenches Areas located on the east side of the Rocky Flats Plant security area Several sites are included in each area because of their physical proximity to each other Each site was assigned a IHSS reference number by Rockwell International (1987c) Figure 1 7 shows the locations of these areas and the sites within each area Also shown are buried barrel locations, determined by visual inspection or magnetometer survey

Site descriptions presented in the following sections are taken from the Rocky Flats Plant CEARP Phase 1 Report (DOE 1986) and the RCRA Part B Operating Permit Application (Rockwell International, 1987c) These

descriptions are based on historical records, aerial photography review, and interviews with Plant personnel. Further characterization of each site based on other historical reports and Phase I RI results is also included in the following discussions.

1.4.1 903 Pad Area

Five sites are located within the 903 Pad Area (Figure 1-8). These sites are:

- 903 Drum Storage Site (IHSS Ref No 112)
- 903 Lip Site (IHSS Ref No 155)
- Trench T-2 Site (IHSS Ref No 109)
- Reactive Metal Destruction Site (IHSS Ref No 140)
- Gas Detoxification Site (IHSS Ref No 183)

Descriptions of each site within the 903 Pad Area are provided in the following sections:

1.4.1.1 903 Drum Storage Site (IHSS Ref No 112)

The 903 Drum Storage Site is located in the eastern portion of the Plant security zone. This area was used from October 1958 to January 1967 for storage of radioactively contaminated oil drums (Calkins, 1970). Presented below is a description of drums stored at the drum storage site from Calkins (1970):

"Most of the drums transferred to the field were nominal 55-gallon drums, but a significant number were 30-gallon drums. Not all were completely full. Approximately three-fourths of the drums were plutonium-contaminated, while most of the balance contained uranium. Of those containing plutonium, most were lathe coolant consisting of a straight-chain hydrocarbon mineral oil (Shell Vitrea) and carbon tetrachloride in varying proportions. Other liquids were involved, however, including hydraulic oils, vacuum pump oil, trichloroethylene, perchloroethylene, silicone oils, acetone still bottoms, etc. Originally, contents of the drums were indicated on the outside, but these markings were made illegible through weathering and no other good records were kept of the contents. Leakage of the oil was recognized early, and in 1959 or possibly earlier ethanolamine was added to the oil to reduce the corrosion rate of the steel drums."

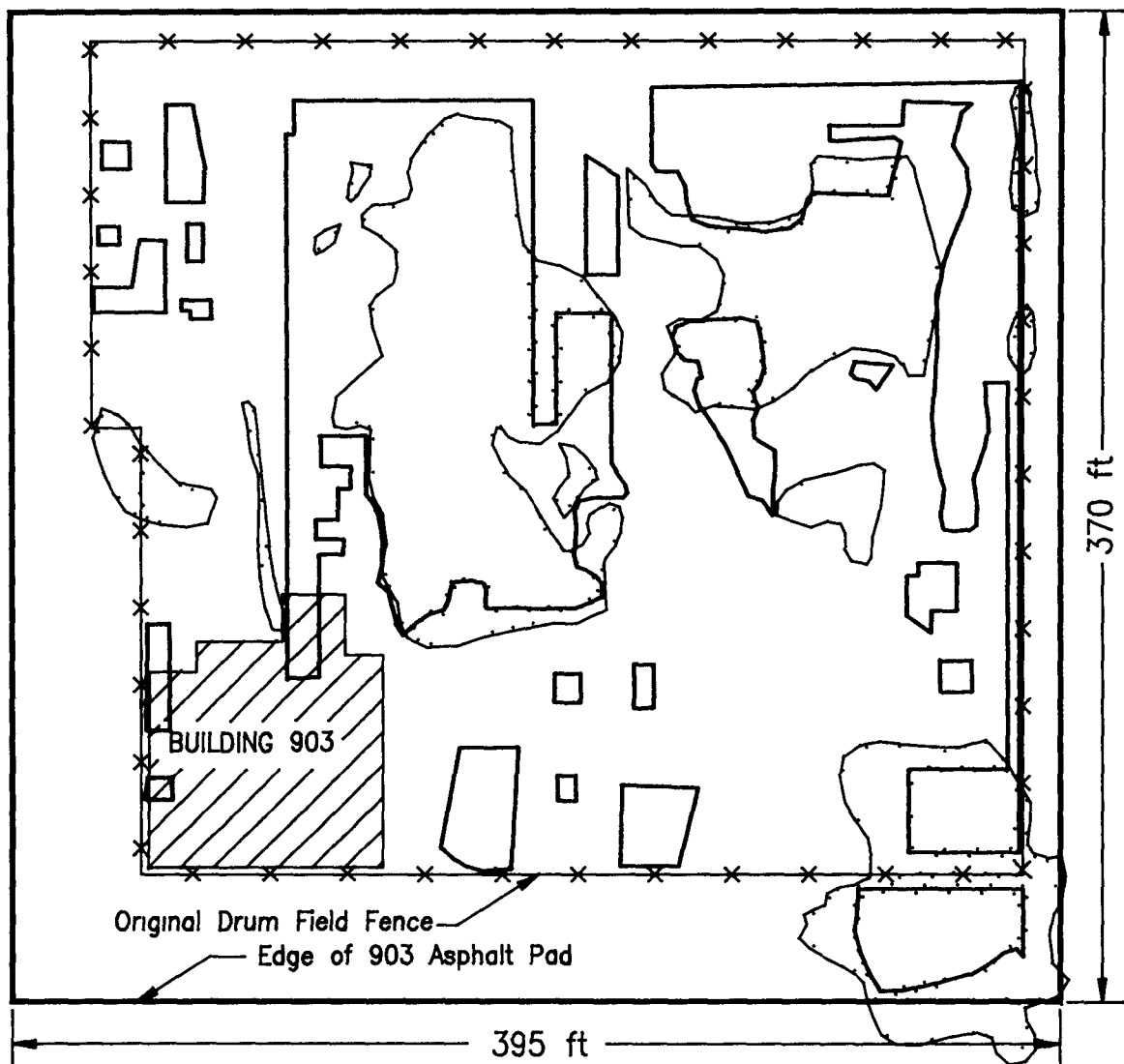
Drum leakage was noted at the 903 Drum Storage Site in 1964 during routine drum handling operations (Dow Chemical, 1971). Corrective action consisted of transferring the contents of leaking drums to new drums and fencing the area to restrict access (Dow Chemical, 1971). Approximately 420 drums leaked to some degree, and of these, an estimated 50 leaked their entire contents (Dow Chemical, 1971). An estimated 5,000 gallons of liquid (Freiberg, 1970) containing 86 grams (g) [5.3 Curies (Ci)] of plutonium leaked into the soil (Dow

Chemical, 1971) A heavy rainstorm in 1967 spread contaminants to a ditch south and southeast of the drum storage site (Dow Chemical, 1971), however, the location of the ditch is not provided by this reference. During an investigation conducted by the AEC Health and Safety Laboratory (HASL), it was estimated that approximately 125 grams of plutonium-239 (Pu-239) was released from the 903 Drum Storage site and redistributed by winds (Krey and Hardy, 1970).



Figure 1-9 outlines drum locations and soil staining at the 903 Drum Storage Site based on a review of historical aerial photography. As seen on this figure, drum storage occurred primarily in the northern and eastern portions of the area. Drums were not stored in the southwest portion where Building 903 was constructed in 1967, and were only briefly stored at the southeast corner. It appears that the drums stored south of the fenced area were placed at this location during clean-up operations, as they appear only in the 1968 aerial photos.

The shipment of drums to the 903 Drum Storage Site ended in January 1967 when drum removal efforts began. Removal of all drums and wastes was completed in June 1968. Presented below is a chronology of the 903 Drum Storage Site clean up as described by Freiberg (1970).

- "From January 23, 1967, through March 10, 1967, uranium oil drums which were in good condition were transferred to Building 774 and processed.
- Building 903 on March 10, 1967, started processing oil drums. This building was designed to prefilter the oil prior to transferring plutonium contaminated oil to Building 774 for final processing.
- From March 10, 1967, through May 18, 1967, there were a total of 191 drums of plutonium contaminated oil filtered and shipped to Building 774.
- On May 18, 1967, operations at Building 903 were discontinued due to the amount of time this process was taking.
- Drum-to-drum transfer in the field began May 18, 1967, and the drums were [SIC] shipped to Building 774 without prior filtration in Building 903.
- From March 17, 1967, through May 10, 1967, in addition to the plutonium transfers, there were 297 drums of uranium contaminated Alk-Tri waste shipped to Building 774 and processed.
- May 10, 1967, through May 28, 1968, a total of 4,826 drums containing 50 gallons of oil each were sent to Building 774 and processed.
- In addition to the oil storage area drums, there were a total of 650 drums from Building 776 current generation sent to Building 774 for processing. A pipeline installed from Building 776 to Building 774 eliminated this additional oil drum generation.
- During the transfer operations, it was noted that at the bottom of all drums a deposit of sludge remained after removal of the oil. This sludge varied in depth from 1/2 inch to 3 inches and averaged approximately 1 inch. By drum counter results the sludge within the empty drums contained a total of 5,152 grams of plutonium. These empty drums were later disposed of by



EXPLANATION

-  AREA OF SOIL STAINING BASED ON AERIAL PHOTOGRAPHS FROM 4/29/67, 4/10/68, 5/24/69
-  BARREL STORAGE LOCATIONS BASED ON AERIAL PHOTOGRAPHS FROM 5/5/63, 4/29/65, 4/29/67, 9/10/68

NOTE. BUILDING 903 LOCATION BASED ON AERIAL PHOTOGRAPHS FROM 4/10/68

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APPROXIMATE LOCATIONS OF DRUM
STORAGE-903 PAD
DRUM STORAGE SITE

FIGURE 1-9

February, 1991

adding Oil Dry and MicroCel to absorb the sludge. The drums containing the plutonium sludge and absorbent were then incased in plastic, placed in boxes, and shipped to the burial grounds." The location of the burial grounds is not provided by Freiberg (1970)

There were originally a total of 5,237 drums at the drum storage site when clean-up operations began in 1967. After transfer of the contents to new drums, 4,826 drums were transported to Building 774 of which 3,572 drums contained plutonium-contaminated oil. This leaves unaccounted the contents of 411 drums. The most probable explanation for this discrepancy, according to Freiberg (1970), is a combination of the following factors:

- All of the drums originally sent to the storage site were not completely full
- Some of the volume was taken up by the sludge which was discarded with the empty barrels
- Leakage out of the barrels and onto the ground occurred

Information provided by Freiberg (1970) indicates that an estimated 5,000 gallons of oil leaked from drums onto the ground at the drum storage site. This estimate was based on the memory and knowledge of those involved in site operations (Freiberg, 1970). Based on oil samples taken from barrels, the average plutonium concentration was 4.54×10^{-3} grams per liter (g/l) [280 microCuries per liter ($\mu\text{Ci/l}$)] Thus, approximately 86 g (5.3 Ci) of plutonium were released to soils at the drum storage site (Freiberg, 1970).

In November 1968, site grading began at the 903 Drum Storage Site in preparation for applying an asphalt cap over the area. This work included moving "slightly" contaminated soil from around the fenced area to inside the fenced area (Freiberg, 1970). A total of 33 drums of radioactively contaminated rocks were removed from the area in May 1969, and two courses of clean fill material were placed over the site during the late summer of 1969. The disposal location of the 33 drums was not provided by Freiberg (1970) and is unknown. The asphalt was applied in October 1969, and in February 1970 additional road base course material was applied to soils directly east and south of the asphalt pad due to soil contamination (Freiberg, 1970).

The asphalt containment cover is rectangular and oriented north-south (370 feet) and east-west (395 feet). The pad dips slightly to the northeast at a drop of one foot per 100 feet. The asphalt cover is approximately eight centimeters (cm) (3.2 inches) thick and it is underlain by approximately fifteen cm (6 inches) of loose gravel and eight cm (3.1 inches) of fill dirt (Navratil, et al, 1979).

1.4.1.2 903 Lip Site (IHSS Ref No 155)

During drum removal and clean-up activities associated with the 903 Drum Storage Site, winds redistributed plutonium beyond the pad primarily to the south and east. An estimated one Ci (16.3 g) of plutonium was redistributed beyond the asphalt pad, and of that one Ci, approximately 0.56 Ci (9.1 g) is believed to have been

deposited in the 903 Lip Site (Barker, 1982) The most contaminated area was immediately adjacent to the pad to the south and southeast Surveys at the time of the drum removal project, and subsequent annual soil sampling from 1969 to 1972, showed a maximum plutonium concentration of 2,258 picoCuries per gram (pCi/g) [5,680 disintegrations per minute per gram (dpm/g)] in the top five cm (two inches) of soil at the 903 Lip Site (Barker, 1982)

Soil clean-up efforts were undertaken in 1976, 1978, and 1984 to remove plutonium-contaminated soils from three different areas within the 903 Lip Site The 1976 soil removal operation began in June 1976 and ended in September 1976 This cleanup consisted of hand-excavating contaminated soils from an area in the vicinity of the Reactive Metal Destruction Site until soil contamination levels were below the detection limit of the Field Instrument for Detection of Low Energy Radiation (FIDLER) The detection limit of the FIDLER is 250 counts per minute (cpm) The FIDLER "counts" are an instrument dependent measure of surface activity and cannot be converted to plutonium concentration in the soil The excavated area was covered with clean top soil and reseeded with native grasses Thirty-five boxes weighing a total of 125,000 pounds were removed and shipped off site for disposal following the 1976 cleanup (Barker, 1982) The off-site disposal location was not provided by Barker (1982) Recent radiological surveys have been conducted to further assess radioactive contamination These include an aerial gamma survey conducted in July 1989 (EG&G, 1990h)

The 1976 soil removal technique hand-excavation was inefficient considering the large amount of contaminated soils requiring removal at the 903 Lip Site In June 1978, a second soil removal project began north of the 1976 removal site using a front-end loader alone or in conjunction with a bull dozer All soil that exceeded 2,000 cpm, as determined by a FIDLER survey, was removed Cleaned areas were resurveyed and soil removal continued until background readings (approximately 250 cpm by a FIDLER survey) were obtained Topsoil was then applied to the excavated area, and the site was revegetated with native grasses During the 1978 soil removal, 1448 boxes weighing approximately 4.7 million pounds were removed and shipped off-site (Barker, 1982) The off-site disposal location was not provided by Barker (1982)

Approximately 0.5 Ci (8.2 g) of plutonium were removed from the 903 Lip Site during the first two soil removal projects This quantity is based on an average soil plutonium concentration of 545 pCi/g (1,200 dpm/g) and a soil density of one gram per cubic centimeter (g/cm^3) (Barker, 1982)

A third soil cleanup was performed along the eastern edge of the 903 Lip Site in 1984 A total of 214 tri-wall pallets of contaminated soil were removed from the area, however, the soil disposal location was not provided by Setlock (1984) The excavated area was backfilled with clean topsoil (Setlock, 1984)

1 4 1 3 Trench T-2 Site (IHSS Ref. No. 109)

Trench T-2 is located south of the 903 Drum Storage Site and west of the Reactive Metal Destruction Site. This trench was used prior to 1968 for the disposal of sanitary sewage sludge and flattened drums contaminated with uranium and plutonium. This trench is believed to measure approximately 15 feet wide by 200 feet long by 5 feet deep (Rockwell International, 1987c). Barrels were noted in the western end of Trench T-2 during 1987 investigations (Figure 1-8).

1 4 1 4 Reactive Metal Destruction Site (IHSS Ref. No. 140)

The Reactive Metal Destruction Site is located on the hillside south of the 903 Drum Storage Site. This site was used during the 1950s and 1960s primarily for the destruction of lithium (Li) metal (DOE, 1986). Approximately 400 to 500 pounds of metallic lithium were destroyed on the ground surface in this area and the residues, primarily nontoxic lithium carbonate, buried (Illsley, 1978). Smaller unknown quantities of sodium (Na), calcium (Ca), and magnesium (Mg), solvents, and unknown liquids were also destroyed at this location (Illsley, 1978). Historical references do not indicate the method by which constituents were destroyed at the site.

Based on review of historical aerial photography, the Reactive Metal Destruction Site was used from 1968 to 1971. Barrels were noted in the southwestern corner of IHSS 140 during 1987 investigations (Figure 1-8).

1 4 1.5 Gas Detoxification Site (IHSS Ref. No. 183)

Building 952, located south of the 903 Drum Storage Site, was used to detoxify various gases from lecture bottles between June 1982 and August 1983. The lecture bottles held approximately one liter of compressed gas each. The gases consisted of various types of nitrogen oxides, chlorine, hydrogen sulfide, sulfur tetrafluoride, methane, hydrogen fluoride, and ammonia which were used in Plant research and development work. Gas detoxification was accomplished by using various commercial neutralization processes available at the time. After neutralization, glassware used in the process was triple-rinsed, crushed, and deposited in the present landfill. The neutralized gases released to the environment during detoxification would no longer be detectable (Rockwell International, 1987c).

1 4 2 Mound Area

The Mound Area is composed of four sites (Figure 1-8). These are

- Mound Site (IHSS Ref. No. 113)
- Trench T-1 Site (IHSS Ref. No. 108)

- Oil Burn Pit No 2 Site (IHSS Ref No 153)
- Pallet Burn Site (IHSS Ref No 154)

These sites are described individually below

1.4.2.1 Mound Site (IHSS Ref. No. 113)

The Mound Site, located north of Central Avenue in the eastern Plant security area, was used between April 1954 and September 1958 for drum disposal. Approximately 1,405 drums containing primarily depleted uranium (U) and beryllium (Be) contaminated lathe coolant (a mixture of about 70 percent hydraulic oil and 30 percent carbon tetrachloride) were placed at the Mound Site (Rockwell International, 1987c). [Records do not indicate that the barrels were actually buried (Calkins, 1970)]. It is likely that some of the coolant also contained enriched uranium and plutonium (Rockwell International, 1987c). Some drums also contained Percene (Smith, 1975). Percene was a brand name of tetrachloroethane (PCE) (Sax and Lewis, 1987). Some of the drummed wastes placed in the Mound Site were in solid form (Rockwell International, 1987c).

Cleanup of the Mound Site was accomplished in May 1970, and the materials removed were packaged and shipped to an off-site DOE facility for disposal. Listed below is an inventory of the 1,405 drums removed from the Mound Site in 1970 (Dow Chemical, 1971).

<u>No. of Drums</u>	<u>Contents</u>
903	30-gallon drums of depleted uranium solid waste
21	30-gallon drums of depleted uranium oil waste
12	30-gallon drums of plutonium contaminated oil waste "The plutonium content was so low that it was measurable only by the most sensitive laboratory techniques"
102	55-gallon drums of depleted uranium solid waste
282	55-gallon drums of depleted uranium oil waste
<u>85</u>	55-gallon drums of enriched uranium oil waste
1,405	TOTAL DRUMS

Subsequent surficial soil sampling in the vicinity of the excavated Mound Site indicated 0.8 to 112.5 dpm/g (0.4 to 51 pCi/g) activity. This radioactive contamination is thought to have come from the 903 Drum Storage Site via wind dispersion rather than from the Mound Site, as it was limited to the surface (Rockwell International, 1987c).

1 4 2 2 Trench T-1 Site (IHSS Ref. No. 108)

The trench was used from 1954 until 1962 and contains approximately 125 drums filled with approximately 25,000 kilograms (kg) (55,115 pounds) of depleted uranium chips (Dow Chemical, 1971), and some plutonium chips coated with small amount of lathe coolant (hydraulic oil and carbon tetrachloride) (Rockwell International, 1987c) The estimated dimensions of Trench T-1 are 15 feet wide by 200 feet long by 5 feet deep (Rockwell International, 1987c) Trench T-1 was covered with about two feet of soil, and the corners were marked (Rockwell International, 1987c) Figure 1-8 illustrates the location of Trench T-1 and the location of barrels determined by visual inspection or magnetometer survey during the Phase I RI

Weed cutting activities in October and November 1968 unearthed two drums inadequately covered with fill material Both drums were sampled and analyzed for total plutonium and uranium content before they were disposed off-site (Illsley, 1983) The off-site disposal location was not provided by Illsley (1983) One of the drums sampled contained an oil/water mixture with 55 pCi/g of plutonium and 2.3×10^5 pCi/g of uranium The other drum contained an oily sludge with 4.6 pCi/g of plutonium and 1.2×10^5 pCi/g uranium (Illsley, 1983)

1 4 2 3 Oil Burn Pit No. 2 Site (IHSS Ref. No. 153)

Oil Burn Pit No. 2 is actually two parallel trenches which were used in 1957 and from 1961 to 1965 to burn approximately 1,082 drums of oil containing uranium (Rockwell International, 1987c) In March and April of 1957, the contents of an estimated 169 uranium-contaminated waste oil drums were burned No further burning took place until 1961 Frequent burning of waste oil took place from June 1961 to May 1965 The contents of approximately 914 drums were burned during this time The drums used for the oil burning operations were generally reused, however, 300 empty drums were discarded by flattening and burying them in the burning pits (Dow Chemical, 1971) The uranium concentrations of the burned waste oil are unknown The residues from the burning operations and the flattened drums were covered with backfill In 1978 the area was excavated to a depth of approximately five feet, and 239 boxes (56 cubic feet per box) of contaminated soil were removed and shipped off-site to an authorized DOE disposal site (Illsley, 1983) The specific off-site disposal location was not provided by Illsley (1983)

1 4 2 4 Pallet Burn Site (IHSS Ref. No. 154)

An area southwest of Oil Burn Pit No. 2 was reportedly used to destroy wooden pallets in 1965 The types of hazardous substances or radionuclides that may have been spilled on these pallets is unknown This site was cleaned up and reclaimed in the 1970s (DOE, 1986) Two locations for the Pallet Burn site are shown on Figure 1-8 The westernmost location was reported by Owen and Steward (1973) However, based on review

of historical aerial photographs, there was no disturbance at this western location. The eastern location was identified from 1963 and 1965 aerial photography of the area.

1 4 3 East Trenches Area

The East Trenches Area consists of nine burial trenches and two spray irrigation sites. These sites are

- Trench T-3 (IHSS Ref No 110)
- Trench T-4 (IHSS Ref No 111 1)
- Trench T-5 (IHSS Ref No 111 2)
- Trench T-6 (IHSS Ref No 111 3)
- Trench T-7 (IHSS Ref No 111 4)
- Trench T-8 (IHSS Ref No 111 5)
- Trench T-9 (IHSS Ref No 111 6)
- Trench T-10 (IHSS Ref No 111 7)
- Trench T-11 (IHSS Ref No 111 8)
- East Spray Irrigation Sites (IHSS Ref Nos 216 2 and 216 3)

Trenches T-3, T-4, T-10, and T-11 are located north of the east access road, and Trenches T-5 through T-9 are south of the east access road. The wastes in these trenches have not been disturbed since their burial. The spray irrigation areas are located east of Trenches T-5 through T-9 (Figure 1-8).

1 4 3 1 Trenches T-3 through T-11 (IHSS Ref Nos. 110 and 111.1-111.8)

These trenches, as well as Trench T-2, were used from 1954 to 1968 for disposal of approximately 125,000 kg of sanitary sewage sludge contaminated with uranium and plutonium, and approximately 300 flattened empty drums contaminated with uranium (Illsley, 1983). Radiation content of the sewage sludge ranged from 8.4×10^5 disintegrations per minute per kilogram (dpm/kg) (382 pCi/g) to 7.9×10^6 dpm/kg (3,590 pCi/g) (Owen and Steward, 1973). "Earlier pits involve mostly uranium with an increasing plutonium fraction in later pits" (Owen and Steward, 1973). Total alpha radioactivity in Trenches T-2 to T-8 is estimated to be 100 to 150 millicuries (0.1 to 0.15 Ci) (Dow Chemical, 1971). Trenches T-4 and T-11 also contain some plutonium- and uranium-contaminated asphalt planking from the solar evaporation ponds (Illsley, 1983). The locations of Trenches T-3 through T-11 are shown in Figure 1-8 as well as the location of the barrels as determined by visual inspection and/or magnetometer survey.

According to Illsley (1983), samples were collected from Trenches T-9, T-10, and T-11, and the results were as follows

"Samples from T-11 contained plutonium in the range from 4.5 to 50 pCi/g and uranium-238 in the range between 0.9 and 158 pCi/g. Trench T-10 was found to contain uranium in the range between 40 and 126 pCi/g and Pu-239 in the range from 0.18 to 14 pCi/g. Plutonium concentrations in collected samples varied from 0.40 to 68 pCi/g and uranium was found in the range between 2.4 and 450 pCi/g in Trench T-9."

The sampling dates and collection methods of these samples are unknown.

1.4.3.2 East Spray Irrigation Sites (IHSS Ref. Nos. 216.2 and 216.3)

IHSS numbers 216.2 and 216.3 were used for spray irrigation of sewage treatment plant effluent. These areas have been designated as IHSSs because effluent containing low concentrations of chromium (Cr) was inadvertently sprayed in the area in February and March 1989. The chromium entered the sanitary sewage treatment plant on February 23, 1989, subsequent to a spill of chromic acid in Building 444 (Rockwell International, 1989e).

2.1 PHASE I REMEDIAL INVESTIGATION

The Phase I RI consisted of the following field activities

- Electromagnetic, resistivity, and magnetometer geophysical surveys
- A soil gas survey
- Soil sample collection from 33 boreholes (Figure 2-1 and Table 2-1)
- Completion of 10 alluvial and 14 bedrock monitoring wells (Figure 2-1)
- Ground-water sampling of new and previously existing wells
- Slug testing of 13 wells
- Packer testing of cored bedrock wells
- Collection of 22 surface water and seep samples
- Air monitoring for total long-lived alpha plutonium and volatile organics during field activities

In addition to the Phase I investigation at the 903 Pad, Mound, and East Trenches Areas, several monitor wells were installed in these areas as part of a Plant-wide hydrogeologic investigation in 1986 (Rockwell International, 1986e and Table 2-1). Surface water, soil, and air samples have also been collected at these areas as part of various investigations. Section 2.2 presents results of the Phase I RI and a brief characterization of each pathway at the 903 Pad, Mound, and East Trenches Areas. The nature and extent of contamination associated with these pathways is discussed in Section 2.3, and Section 2.4 presents the site conceptual model.

2.2 SITE PHYSICAL CHARACTERISTICS

A site-specific conceptual model of the 903 Pad, Mound, and East Trenches Areas has been developed based on the Phase I RI results as well as previous and subsequent investigations. This model describes contaminant sources and pathways through which contaminant transport may occur from these areas.

Table 2-1
903 PAD, MOUND, AND EAST TRENCHES AREAS
MONITORING WELL DATA

Well Number	Geologic Strata of Completion	Ground Surface Elev (ft)	Top of Casing Elev (ft)	Depth to Top of Screen	Depth to Bottom of Screen	Total Depth (ft)	Depth to Bedrock (ft)	Bedrock Elevation	Northing Coordinate (ft) -RFP	Easting Coordinate (ft) -RFP	State Northing (ft)	State Easting (ft)
3306	Qrf	5949.28	5950.70	2.99	7.34	7.34	7.00	5942.28	36960.93	21896.47	749962.6590	2085000.2370
3906	Qrf	5904.91	5906.61	5.00	31.50	31.50	30.50	5874.41	38288.72	27591.82	751290.6447	2090695.5130
4106	Qrf	5940.03	5941.83	3.90	44.70	44.70	44.40	5895.63	36611.43	25437.08	749613.2570	2088540.8520
4206	Qrf	5954.34	5956.43	6.12	29.70	29.70	28.60	5925.74	36565.80	24007.88	749567.5710	2087111.6510
4306	Qrf	5970.39	5972.49	3.99	16.75	16.75	16.50	5953.89	36415.05	22761.70	749416.7604	2085865.4760
1087	Qrf	5981.96	5983.53	3.50	12.00	12.00	11.00	5970.96	35959.99	22180.04	748947.0158	2085289.2754
1587	Qrf	5970.89	5972.99	5.80	22.06	22.53	22.00	5948.89	36020.14	23139.88	749010.3218	2086248.6590
1787	Qrf	5967.56	5969.53	3.50	22.00	25.75	25.00	5942.56	36424.92	23200.70	749415.1940	2086308.1281
1987	Qrf	5967.98	5969.84	3.50	11.65	11.89	11.40	5956.58	36633.42	23064.85	749623.1990	2086171.6264
2487	Qrf	5957.79	5959.66	3.50	13.60	13.85	13.40	5944.39	36759.05	23640.05	749750.6926	2086746.2613
2687	Qrf	5954.06	5955.97	4.00	13.45	13.70	13.20	5940.86	36261.48	24381.98	749255.6958	2087489.6385
2787	Qrf	5947.52	5949.73	3.50	43.00	43.25	42.75	5904.77	36442.01	24944.62	749438.0421	2088051.5380
3287	Qrf	5946.12	5948.03	36.00	46.55	46.80	46.30	5899.82	36513.70	25256.21	749510.7405	2088362.8092
3387	Qrf	5945.27	5947.15	15.00	20.00	20.25	19.75	5925.52	36859.07	24815.13	749854.5591	2087920.7058
3587	Qrf	5949.36	5951.42	3.50	9.35	9.60	9.10	5940.26	36981.20	24162.59	749974.5030	2087267.9351
6306	Qc	5900.40	5902.04	3.80	15.25	15.50	14.80	5885.60	35155.84	22641.51	748144.5996	2085753.2740
6706	Qc	5796.26	5797.73	2.50	14.75	14.75	14.00	5782.26	35706.56	27253.77	748710.4048	2090362.5100
2987	Qc	5812.42	5814.40	3.50	20.30	20.50	19.80	5792.62	35094.87	24249.82	748088.9555	2087361.3703
4487	Qc	5949.53	5951.26	1.50	3.50	3.70	3.20	5946.33	35317.96	22323.69	748305.6314	2085435.0051
3506	Qvf	5909.20	5911.54	0.00	11.60	11.60	10.30	5898.90	37176.97	23114.38	750178.7010	2086218.1420
3606	Qvf	5881.94	5883.78	3.50	6.49	6.50	5.50	5876.44	37395.41	23715.31	750397.1536	2086819.1070
3706	Qvf	5792.02	5794.15	3.29	8.55	8.55	7.75	5784.27	38561.44	25758.47	751563.0018	2088862.4820
6406	Qvf	5834.48	5836.46	3.41	9.00	9.00	8.80	5825.68	36683.82	22497.26	747685.5186	2085601.1100
6506	Qvf	5782.75	5784.40	2.50	8.00	8.00	7.10	5775.65	34886.65	24389.54	747888.4362	2087493.3790
6606	Qvf	5685.12	5686.73	2.50	6.50	6.50	5.80	5679.32	33638.66	28151.55	746640.6086	2091255.4530
2187	Qvf	5927.58	5929.36	3.23	10.40	10.56	10.40	5917.18	36980.21	22693.84	749968.6664	2085799.5648

KEY TO GEOLOGIC STRATA Qrf-Rocky Flats Alluvium Qc-Colluvium Qvf-Valley Fill Alluvium Kac-Claystone Kass-Sandstone

Sheet 1 of 2

Table 2-1 (Continued)
903 PAD, MOUND, AND EAST TRENCHES AREAS
MONITORING WELL DATA

Well Number	Geologic Strata of Completion	Ground Surface Elev (ft)	Top of Casing Elev (ft)	Depth to Top of Screen	Depth to Bottom of Screen	Total Depth (ft)	Depth to Bedrock (ft)	Bedrock Elevation	Northing Coordinate (ft)-RFP	Easting Coordinate (ft)-RFP	State Northing (ft)	State Easting (ft)
0171	Kacl	5950 00	5950 83	0 00	29 17	30 05	0 00	0 00	35823 90	23205 50	0 0000	0 0000
0271	Kacl	5936 20	5936 79	0 00	28 64	29 23	0 00	0 00	35528 12	22831 33	0 0000	0 0000
0174	Kacl	5968 00	5968 80	0 00	24 16	24 96	0 00	0 00	36643 80	23069 00	0 0000	0 0000
0374	Kacl	5950 20	5951 31	0 00	23 98	25 04	0 00	0 00	36944 90	23884 50	0 0000	0 0000
6286	Kass	5897 54	5898 75	25 22	35 19	35 19	22 00	5875 54	35154 34	22613 19	748156 0499	2085717 0180
09878R	Kass	5980 22	5981 72	14 50	32 15	32 40	12 70	5967 52	36080 84	22239 33	749068 0299	2085348 1453
11878R	Kass	5913 57	5915 36	15 20	20 25	20 50	5 20	5908 37	35419 39	22989 24	748409 2366	2086100 0436
12878R	Kass	5934 74	5936 49	4 92	10 00	10 25	4 00	5930 74	35590 92	22956 17	748580 6049	2086066 4205
14878R	Kass	5855 00	5856 73	19 00	24 05	24 30	5 20	5849 80	35236 67	23504 68	748228 2626	2086615 9564
23878R	Kass	5972 34	5974 49	17 19	37 61	37 85	15 25	5957 09	36415 15	22802 78	749404 1201	2085910 3415
25878R	Kass	5958 91	5960 96	17 50	43 45	43 70	16 50	5942 41	36727 08	23641 38	749718 7298	2086747 6965
34878R	Kass	5949 04	5951 12	19 80	63 35	63 59	7 50	5941 54	36985 79	24189 80	749979 1830	2087295 1168
3486	Kass	5910 44	5912 78	44 24	56 25	56 25	16 10	5894 34	37171 41	23088 39	750173 1389	2086192 1520
4086	Kass	5941 23	5942 21	87 98	111 50	111 50	45 00	5896 23	36612 84	25398 09	749614 6648	2088501 8570
14878R	Kass	5969 06	5970 98	100 00	125 00	125 24	21 90	5947 16	36139 59	23140 49	749129 7454	2086248 8779
18878R	Kass	5967 38	5969 45	127 00	133 45	133 70	24 60	5942 78	36413 74	23231 24	749404 1222	2086338 6941
20878R	Kass	5968 10	5970 10	107 26	116 11	116 36	11 80	5956 30	36644 48	23048 42	749634 1973	2086155 1645
22878R	Kass	5930 70	5932 49	81 41	88 46	88 70	12 80	5917 90	36934 99	22715 72	749923 5377	2085821 5930
28878R	Kass	5947 17	5950 03	187 37	197 37	197 70	43 50	5903 67	36442 31	24983 42	749438 4716	2088090 3222
30878R	Kass	5811 87	5813 80	85 79	94 35	94 35	16 00	5795 87	35095 15	24312 43	748089 4398	2087423 9554
31878R	Kass	5945 02	5947 56	110 66	129 41	129 64	45 00	5900 02	36502 97	25201 86	749499 8322	2088308 5132
34878R	Kass	5945 21	5947 22	97 29	104 24	104 49	20 00	5925 21	36840 38	24825 73	749835 9078	2087931 3614
45878R	Kass	5949 42	5951 00	89 50	101 05	101 30	4 00	5945 42	35325 47	22340 05	748313 1987	2085451 3360

2 2 1 Geology

2 2 1 1 Surficial Geology

Surficial materials at the 903 Pad, Mound, and East Trenches Areas consist of the Rocky Flats Alluvium, colluvium, and valley fill alluvium unconformably overlying bedrock (Figure 2-2). In addition, there are a few isolated exposures of bedrock. The area is situated on a pediment covered with Rocky Flats Alluvium which extends eastward from the Plant. The Rocky Flats Alluvium consists of a poorly to moderately sorted, poorly stratified deposit of clay, silt, sand, gravel, and cobbles. A portion of the 903 Pad Area extends south off the pediment toward the South Interceptor Ditch (SID). Colluvium is present on the hillside south of the 903 Pad and East Trenches Areas, and on the hillside north of the Mound and East Trenches Areas. Valley fill alluvium is present in the drainage of Woman Creek south of the 903 Pad and East Trenches Areas and in the South Walnut Creek drainage north of the Mound Area.

Buried paleodrainages and ridges eroded into the Arapahoe Formation bedrock surface are present at the base of the Rocky Flats Alluvium (Figure 2-3). A relatively small paleogully is present, starting near the southeast corner of the Mound Area and extending southeast, where it is truncated by the hillside. A larger paleogully starts south of the east end of the East Trenches and trends northeast, traversing the central portion of the East Trenches. A paleoridge is present on the north side of this paleogully, starting in the Mound Area and trending east-northeast across the northwest portion of the East Trenches Area. A topographic high in the bedrock surface occurs on the south side of the larger paleogully just south of the central portion of the East Trenches Area.

2 2 1 2 Bedrock Geology

Significant work has been conducted recently to further characterize bedrock at Rocky Flats. A draft Geologic Characterization Report for the Rocky Flats Plant (EG&G, 1990b) was prepared based on a comprehensive literature search, reprocessing and describing previously obtained core samples, reprocessing previously obtained seismic data, and collecting and analyzing selected samples for grain size analyses. The geologic characterization is an ongoing program that will incorporate all geologic information Plant-wide for continued refinement of the working geologic model. In addition to these efforts, high-resolution seismic reflection profiling was conducted in the OU No. 2 area (EG&G, 1990c). These two studies were conducted concurrently and the description of bedrock geology presented in this work plan utilizes the results of both.

The Cretaceous-age Arapahoe Formation underlies surficial materials at the 903 Pad, Mound, and East Trenches Areas. The high-resolution seismic reflection program indicated that the Arapahoe Formation dips at less than two degrees to the east. The Arapahoe Formation, which is approximately 250 feet thick in the vicinity of the Plant (EG&G, 1990b), consists of fluvial claystones with interbedded sandstones, siltstones, and occasional lignite deposits. Contacts between these lithologies are both gradational and sharp.

The Arapahoe Formation was deposited by meandering streams that flowed east-southeast from the Front Range Uplift (Weimer, 1973). Fining-upward graded sandstone sequences within the formation are representative of both laterally accreted point bar deposits and floodplain splay deposits. Laterally accreted point bar deposits occur by the slow migration of fluvial channels, and splay deposits are formed by breaching of channel banks during floods (Blatt, et al., 1980). Overbank flood deposits consist of very fine sand and mud deposited near the stream channel or on the stream flood plain. Channel fill deposits are formed in abandoned channels by a reduction in stream discharge or by cutoff of a meander (formation of oxbow lakes) (Blatt, et al., 1980).

Based on previous investigations, the ongoing geologic characterization by EG&G, bedrock in the 903 Pad, Mound and East Trenches Areas is predominantly claystone (EG&G, 1990a). However, six channel sandstone intervals have been preliminary identified beneath the Rocky Flats Plant. These are general stratigraphic intervals, each of which contains sandstones only at some locations. They have been sequentially numbered according to increasing depth. Thus, Arapahoe Sandstone No. 1 is the uppermost sandstone, which subcrops in many areas. Arapahoe Sandstone No. 6 is present at or near the base of the Arapahoe Formation.

Generally, the Arapahoe Sandstones that occur within 30 to 40 feet of the base of the alluvium are oxidized and are pale orange, yellowish-gray, and dark yellowish-orange. The sandstones that are not in the weathered zone are light gray and olive-gray. Most of the sandstones are very fine- to medium-grained, poorly- to moderately-sorted, subangular to subrounded, silty, clayey, and quartzitic, with trough and planar cross-stratification. The claystones and silty claystones are light to medium olive-gray, occasionally olive-black with some dark yellowish-orange claystones in the weathered intervals near the base of the alluvium. The yellowish-orange and yellowish-brown color is the result of the iron oxide staining.

The draft Geologic Characterization Report (EG&G, 1990b) included mapping the estimated areal extent of Arapahoe Sandstone Nos. 1, 3, and 4. The lateral extent of channel deposits in each of these lithologic intervals was estimated based on previous borehole formation. Figure 2-4 shows the estimated lateral extent and thickness isopachs of the Arapahoe Sandstone No. 1 and the estimated lateral extents of the Arapahoe Sandstone Nos. 3 and 4. Sandstone was also found in the Nos. 2 and 5 intervals in several boreholes in the OU No. 2 area. However, there was not sufficient information to estimate the lateral extent of sandstones within these intervals.

Significant areas of the Arapahoe Sandstone No 1 are known to subcrop beneath the Rocky Flats Alluvium in the 903 Pad, Mound, and East Trenches Areas. It is believed that nearly the entire area shown as the Arapahoe Sandstone No 1 channel subcrops beneath the Rocky Flats Alluvium. As a result of the significant areal extent of subcropping Arapahoe Sandstone No 1, and since significant contamination has been found in this uppermost sandstone interval, all of the Arapahoe Sandstone No 1 is included in the upper HSU. The conceptual boundary between the alluvial and bedrock components of the RFI/RI is located beneath the Arapahoe Sandstone No 1 as shown in Figure 1-1.

High-resolution seismic reflection profiling (EG&G, 1990c, Rockwell International, 1989f) was conducted to help refine the working model of the bedrock geology, particularly in the OU No 2 area. There are some differences between the draft Geologic Characterization Report and the high-resolution seismic reflection profiling report in the estimated thickness and areal extent of the Arapahoe Sandstone No 1. Since the Arapahoe Sandstone No 1 is considered to be within the upper HSU, further characterization of it and resolution of differences between the Geologic Characterization Report and high-resolution seismic profiling results will be part of the alluvial RFI/RI activities.

2.2.2 Ground-water Hydrology

Unconfined ground-water flow occurs in surficial materials and subcropping sandstones. In addition, subcropping claystone may be saturated in some locations, particularly where weathered and fractured. Confined ground-water flow occurs in lower sandstone units. The majority of wells that have been installed in weathered claystone throughout the Plant are unsaturated.

2.2.2.1 Ground-water Flow System in Upper Hydrostratigraphic Unit

Recharge/Discharge Conditions

Ground water is present in the Rocky Flats alluvium, colluvium, valley fill alluvium, and subcropping sandstones under unconfined conditions. Recharge to the upper HSU occurs as infiltration of incident precipitation and as seepage from ditches and creeks. In addition, retention ponds along South Walnut Creek and Woman Creek probably recharge the valley fill alluvium.

The shallow ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and stream and ditch flow. Alluvial water levels are highest during the spring and early summer months of May and June. Water levels generally decline during late summer and fall, at which time some wells go dry. The shallow ground-water flow system supports ephemeral flow in the creeks.

Alluvial ground water discharges to seeps, surface water drainages, colluvium, and subcropping Arapahoe sandstone at the 903 Pad, Mound, and East Trenches Areas. Seeps occur along the edge of the pediment margin (at the alluvium/bedrock contact) and on the hillside slopes. Seeps on the hillsides may be due to thinning of colluvial materials. Ground water in valley fill materials discharges to Woman or South Walnut Creeks.

Ground-water Flow Directions

Ground-water flow in the unconfined system is generally from west to east. Figure 2-5 presents the potentiometric surface for the upper HSU, measured in April 1988, and represents the most extensive area of saturation for surficial materials and subcropping sandstones which exhibit unconfined conditions. Ground-water flow within the Rocky Flats Alluvium is east-northeast in the area, generally following topography. Ground-water flow directions in the subcropping sandstones are probably influenced by the geometry of the sandstone channels (Figure 2-4). Ground water flowing toward the pediment edges emerges as seeps at the contact between the alluvium/subcropping sandstones and claystone bedrock (contact seeps), is consumed by evapotranspiration, or flows through colluvial materials following topography toward the valley fill alluvium. Once ground water reaches the valley fill alluvium, it either flows down-valley in the alluvium, is consumed by evapotranspiration, or discharges to the creek. During the driest periods of the year, evapotranspiration consumes so much water that there is no flow in either the colluvium or the valley fill alluvium. Wells completed in these areas are dry during some portion of the year.

Ground-water Flow Rates

Hydraulic conductivity values were developed for surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site characterization (Rockwell International, 1986e) and from slug tests performed on select 1986 and 1987 wells during the 1987 Phase I RI (Rockwell International, 1987a). For the Rocky Flats Alluvium, hydraulic conductivities for all tests ranged from 4×10^{-5} centimeters per second (cm/s) at well 39-86 to 5×10^{-2} cm/s at well 42-86. The geometric mean hydraulic conductivity for all tests was 4×10^{-4} cm/s. Based on an average horizontal gradient of 0.02 feet/foot (ft/ft) at the 903 Pad, Mound, and East Trenches Areas, an assumed effective porosity of 0.1, and a mean hydraulic conductivity of 4×10^{-4} cm/s, (Rockwell International, 1987a) the average ground-water velocity in the Rocky Flats Alluvium is 82 feet per year (ft/yr). Based on the ranges of hydraulic conductivity values, ground-water flow velocity ranges from approximately 8 ft/yr to 10,350 ft/yr.

The geometric mean hydraulic conductivity based on drawdown-recovery tests for the Woman Creek valley fill alluvium is 7×10^{-4} cm/s and the range is from 5×10^{-5} cm/s at well 68-86 to 3×10^{-3} cm/s at well 65-86.

No slug tests were performed on wells completed in Woman Creek valley fill. Using an average horizontal gradient of 0.02 ft/ft, an assumed effective porosity of 0.1, and a mean hydraulic conductivity of 7×10^{-4} cm/s, the average ground-water velocity in Woman Creek valley fill is 145 ft/yr (Rockwell International, 1987a). Ground-water flow velocity ranges from 10 to 621 ft/yr based on the range of hydraulic conductivity values.

South Walnut Creek valley fill is less conductive than that along Woman Creek based on lithologic descriptions and hydraulic conductivity tests of well 35-86. A drawdown-recovery test and a slug test have been performed in well 35-86. The hydraulic conductivity of South Walnut Creek Alluvium calculated from the drawdown-recovery test was 9×10^{-5} cm/s. Results of the slug test indicated a hydraulic conductivity of 1×10^{-4} cm/s. Using the mean conductivity of 9.5×10^{-5} cm/s, an effective porosity of 0.1, and an average gradient of 0.02 ft/ft, the average flow velocity in South Walnut Creek valley fill is 20 ft/yr (Rockwell International, 1987a).

The average ground-water flow velocities calculated for various surficial materials assume the materials are fully saturated year-round. However, as discussed above, portions of the Rocky Flats Alluvium, colluvium, and valley fill alluviums are not saturated during the entire year. Based on water level data from the area, alluvial wells are dry approximately three months during the year (generally August through October). Thus, ground-water flow may occur only nine months of the year. This results in reduced average ground-water movement in all alluvial materials (approximately 62 ft/yr in Rocky Flats Alluvium, 110 ft/yr in Woman Creek valley fill alluvium, and 15 ft/yr in South Walnut Creek valley fill alluvium).

2.2.2.2 Confined Ground-water Flow Systems

The greatest potential for ground-water flow in the Arapahoe Formation occurs in the sandstones contained within the claystones. Ground-water recharge to sandstones occurs as infiltration from alluvial ground water where sandstones subcrop beneath the alluvium, and to a very minor extent by leakage from claystones overlying the sandstones.

Following Robson, et al. (1981a) flow within individual sandstones is assumed to be from west to east, but the geometry of the ground-water flow path in the bedrock is not fully understood at this time due to its dependence upon the continuity of the sandstones and their hydraulic interconnection. Also, there is not sufficient information to estimate ground-water flow rates in the lower sandstones at this time. Evaluation of the lateral extent and degree of interconnection of the sandstone units is a primary goal of an ongoing program of profiling the Arapahoe Formation through additional drilling and high resolution seismic reflection studies. This information will be used in conjunction with site hydrologic data to better characterize flow paths in individual sandstones during the Phase II RFI/RI bedrock investigation.

2 2 3 Surface Water Hydrology

2 2 3 1 South Walnut Creek

The headwaters of South Walnut Creek were filled during construction of Plant facilities, and the area is now drained by a series of culverts. The drainage from the Central Avenue area between the 903 Pad and Mound Areas is diverted into a large corrugated metal pipe that discharges into South Walnut Creek beneath a perimeter access road embankment outside of the Perimeter Security Zone (PSZ). A second culvert is a large concrete culvert that diverts storm flows from the area east of Building 991 within the PSZ to South Walnut Creek. This concrete culvert also discharges beneath the perimeter access road and into the South Walnut Creek drainage.

A third culvert diverts flows from the western part of the PSZ to a point downstream of the two culverts described above. The third culvert terminates near the sewage plant discharge channel in South Walnut Creek. The combined flows, typically less than 10 gallons per minute (gpm) based on flow data from the first three quarters of 1989, then enter the South Walnut Creek retention pond system. Below the retention ponds, South Walnut Creek joins North Walnut Creek and an unnamed tributary within the buffer zone before flowing into Great Western Reservoir located approximately one mile east of this confluence.

The South Walnut Creek retention pond system consists of five ponds (B-1, B-2, B-3, B-4, and B-5) that retain surface water runoff and Plant discharges for monitoring and evaluation before downstream release of these waters. All flow downstream of the most downstream pond (Pond B-5) originates from Pond B-5 and is measured and monitored for quality in accordance with the Plant's NPDES permit (discharge point 006). Ponds B-1 and B-2 are reserved for spill control, surface water runoff, or treated sanitary waste of questionable quality, and Pond B-3 is a holding pond for sanitary sewage treatment plant effluent. The normal discharge of Pond B-3 is to a spray system located in the vicinity of the East Trenches. Ponds B-4 and B-5 receive surface water runoff from the central portion of the Plant and occasional discharges from Pond B-3. The surface water runoff received by Pond B-4 is collected by the Central Avenue Ditch and upper reaches of South Walnut Creek (including storm runoff diverted via the two large-diameter culverts). The discharge of Pond B-5 is currently released to retention Pond A-4, located in the North Walnut Creek drainage.

2 2 3 2 Woman Creek

Woman Creek is located south of the Plant with headwaters in largely undisturbed Rocky Flats Alluvium. Runoff from the southern part of the Plant is collected in the SID located due north of the creek and delivered to Pond C-2. Pond C-1 (upstream of C-2) receives stream flow from Woman Creek. The Woman Creek drainage is located in OU No. 5, which is just south of OU No. 2. The discharge from Pond C-1 is diverted

around Pond C-2 into the Woman Creek channel downstream. Water in Pond C-2 is treated and monitored in accordance with the Plant NPDES permit. Treated water from Pond C-2 is then diverted to the Walnut Creek watershed where it is released to the Broomfield Diversion Canal.

Flow in Woman Creek and the SID is intermittent, appearing and disappearing along various reaches. During the 1986 initial site characterization, measurable flow occurred at less than one-half of the ten stations located along Woman Creek and the SID (Rockwell International, 1986e). All recorded flows were less than ten gallons per minute. During the 1986 and 1987 investigations, there was no surface flow in Woman Creek downstream of Pond C-2. The intermittent surface water flow observed for Woman Creek and the SID is indicative of frequent interaction with the shallow ground-water system.

2.2.4 Surficial Soils

Surficial soils of OU No. 2 are predominantly moderately deep to deep, well-drained clay loams of moderate to low permeability. The area is drained by Woman Creek, and soils along the flood plain and low terraces have formed in stratified loamy alluvium. The higher, gently sloping soils are formed from Rocky Flats Alluvium, where gravels and cobbles are common. The hillsides in the area are formed from cobbly, gravelly, and loamy alluvium (mixed sources) or claystone. Runoff is generally rapid and erosion hazard can be severe on the steeper slopes. Numerous soil series occur in the area, however, all belong in the Arguistoll great group with the exception of some entisolls in the drainages (Figure 2-6 and Table 2-2). Arguistolls are generally characterized as well-drained soils with mollic (dark) epipedons, argillic "B" horizons, and calcic "C" horizons. They exist in ustic moisture regimes (limited moisture, but adequate for plant growth during growing season). The two predominant subgroups are Torreritic and Andic, with the Torreritic Arguistolls having more pronounced shrinking and swelling capability (U.S. Department of Agriculture, 1980).

2.3 NATURE AND EXTENT OF CONTAMINATION

2.3.1 Background Characterization

In order to facilitate the interpretation of chemical results in non-background areas, a background characterization program has been implemented to define the spatial and temporal variability of naturally occurring constituents. A plan was completed in January 1989 (Rockwell International, 1989g), field work was conducted, and a draft Background Geochemical Characterization Report was prepared and submitted to the regulatory agencies in December 1989 (Rockwell International, 1989h). The report was recently finalized for submittal in December 1990 (EG&G, 1990g). The document summarizes the background data for ground water, surface water, sediments and geologic materials and identifies preliminary statistical boundaries of

TABLE 2-2
SOIL TYPES EAST OF THE 903 PAD

Series	Family	Phase	Min-Max Slope (%)	Infiltration Rate	Soil Type*
Denver	Torrertic Arguistolls	clay loam	5-9	slow	27
Denver-Kutch	Torrertic Arguistolls	clay loam	5-9	slow	29
Denver-Kutch-Midway	Torrertic Arguistolls	clay loam	9-25	slow	31
Englewood	Torrertic Arguistolls	clay loam	2-5	slow	42
Flatirons	Aridic Paleustolls	sandy loam	0-3	slow	45
Haverson	Ustic Torrifluvents	loam	0-3	moderate	60
Leyden Primen-Standley	Aridic Arguistolls	cobbly clay loam	15-50	slow	80
Midway	Ustic Torriorthents	clay loam	9-30	slow	98
Nederland	Aridic Arguistolls	sandy loam	15-50	moderate	100
Nunn	Aridic Arguistolls	clay loam	0-2	slow	102
Nunn	Aridic Arguistolls	clay loam	2-5	slow	103
Standley-Nunn	Aridic Arguistolls	gravelly clay loam	0-5	slow	149
Willowman-Leyden	Aridic Arguistolls	clay loam	9-30	moderate	174

* Soil Type number corresponds to soil type exhibited in Figure 2-6

Source U S Department of Agriculture, 1980

background variability. Spatial variations in the chemistry of geologic materials and water were addressed by placing sample locations throughout background areas at the Plant. The goal of evaluating temporal variations in water chemistry has not yet been achieved because at least two years of quarterly data are needed. Revision of the background report will continue as additional background data are collected.

The boundaries of background variability were quantified through the calculation of tolerance intervals assuming a normal distribution. Assumptions and statistical analyses of the background tolerance intervals are presented in Rockwell International (1989h). The upper limit of the tolerance interval or the maximum detected value for each parameter analyzed in background ground-water, surface water, sediment, and geologic samples are provided in Tables 2-3 through 2-6, respectively. Maximum detected values are provided where there were insufficient data to calculate tolerance intervals. This condition resulted from there being an insufficient number of samples, or where there was an insufficient number of detectable concentrations for a given analyte. Background samples were initially not analyzed for EPA Contract Laboratory Program (CLP) Target Compound List (TCL) organics, because the background areas are outside of potentially contaminated areas. However, as of first quarter 1990, ground-water and surface water samples are being collected in background areas for volatile organic analysis.

To assess the presence of inorganic contamination at the 903 Pad, Mound, and East Trenches Areas, site-specific chemical data are compared to the background tolerance intervals or the maximum detected value if a tolerance interval could not be calculated. A constituent concentration that is greater than the upper limit of the one-sided 95 percent tolerance interval at the 95% confidence level will be considered to preliminarily represent contamination. Although not statistically significant, a site-specific chemical concentration above the maximum detected background value is considered a very preliminary indication of contamination in the following assessment.

Radionuclides are analyzed by counting subatomic particle emissions, which is a random function. Since radioactive disintegration is a statistical process and therefore has a probability distribution, results are reported as a measured value with an associated two standard deviation propagated error term indicated in parentheses immediately following the measured value. Computation of tolerance intervals for radionuclides did not account for the error term associated with each datum. Techniques are under investigation to account for propagation of error resulting from computation. For the purposes of this plan, the boundaries of the background variability for radionuclides will be the tolerance intervals as computed in the draft Background Geochemical Characterization Report. Site radionuclide concentrations where the error term is larger than the measured value are below the minimum detectable activity (MDA) and are considered not statistically different from background. Measured values which exceed their associated counting errors are considered above background if they are greater than the upper limit of the calculated tolerance interval. Because this comparison does not account for the propagated error associated with the upper limit of the background

TABLE 2-3

**BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
<u>Dissolved Metals</u>							
Aluminum	mg/l	ND	ND	ND	ND	ND	0 327*
Antimony	mg/l	ND	ND	ND	ND	ND	ND 0 0186*
Arsenic	mg/l	ND	ND	ND	ND	ND	ND
Barium	mg/l	ND	ND	ND	ND	ND	ND
Beryllium	mg/l	ND	ND	ND	ND	ND	64 6
Cadmium	mg/l	85	76 8*	138	73 4*	65 7*	ND
Calcium	mg/l	ND	ND	ND	ND	0 0122*	ND
Cesium	mg/l	ND	ND	ND	ND	ND	ND
Chromium	mg/l	ND	ND	ND	ND	ND	ND
Cobalt	mg/l	ND	ND	ND	ND	ND	ND
Copper	mg/l	0 266*	ND	0 94*	ND	ND	ND
Iron	mg/l	ND	ND	ND	ND	0 0106*	ND
Lead	mg/l	ND	0 172*	0 028	031*	9 41*	ND
Lithium	mg/l	5 79*	15 3*	26 57	45 3*	0 292*	0 0182*
Magnesium	mg/l	0 365	0 088*	0 686*	0 126*	ND	ND
Manganese	mg/l	ND	ND	0 003*	008*	0 015*	0 112*
Mercury	mg/l	0 0136*	ND	ND	0 015*	ND	ND
Molybdenum	mg/l	0 0432*	ND	ND	ND	ND	21 89*
Nickel	mg/l	7 73*	ND	ND	ND	ND	0 041*
Potassium	mg/l	ND	ND	0 0114*	ND	ND	ND
Selenium	mg/l	ND	ND	ND	ND	25 6*	599
Silver	mg/l	13 4	98 7*	88	36 9*	ND	0 451*
Sodium	mg/l	0 159*	ND	ND	0 01*	ND	ND
Strontium	mg/l	ND	ND	ND	ND	ND	ND
Thallium	mg/l	ND	ND	ND	ND	ND	ND
Tin	mg/l	ND	ND	ND	ND	ND	ND
Vanadium	mg/l	0 141*	ND	0 0212*	0.107*	ND	0.564
Zinc	mg/l	ND	ND	ND	ND	ND	ND

TABLE 2-3 (Continued)

**BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Other							
Total Dissolved Solids	mg/l	352	520*	947	320*	170*	1761
Carbonate	mg/l	ND	ND	ND	ND	ND	49
Bicarbonate	mg/l	436	470*	719	400*	140*	412
Chloride	mg/l	15	20*	40	11*	15*	607
Sulfate	mg/l	45	86*	150	44*	16*	950
Nitrate	mg/l	2	0	69*	0	1	610
Cyanide	mg/l	0038*	ND	ND	0	ND	ND
pH	----	8.6 (5.98)	7.4* (7.1)**	8.68 (6.12)	8.2* (7.4)**	7.5* (7.2)**	10.57 (7.43)
Dissolved Radionuclides							
Gross Alpha	pCi/l	12,543	27*	13,515	12*	7*	13*
Gross Beta	pCi/l	14,570	12*	18,530	7*	2*	15*
Uranium 233, 234	pCi/l	1,647	11*	6,481	5	1	12,936
Uranium 235	pCi/l	0,000	0.3*	0,232	0	0*	0,135
Uranium 238	pCi/l	0,195	7.7*	5,084	3	0.6*	3,3507
Strontium 89, 90	pCi/l	0,552	0.1*	0,878	0	-0.1*	0.2*
Plutonium 239, 240	pCi/l	0,009	0*	0,012	0	0.01*	0,000
Americium 241	pCi/l	0,000	0*	0,012	0	0.01*	0,019
Cesium 137	pCi/l	0,603	0.2*	0,776	0	0.3*	0.7*
Tritium	pCi/l	309	100*	505	100	100*	731

* - Maximum Detected Value
 ** - Minimum Detected Value
 ND - Not Detected at Contract Required Detection Limit
 () - Tolerance Interval Lower Limit for Two-Sided Parameter

TABLE 2-4

**BACKGROUND SURFACE WATER (ROUNDS 1 and 2)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Round 1 (7 samples)**	
		Total	Dissolved
<u>Metals</u>			
Aluminum	mg/l	0 916*	0 485*
Antimony	mg/l	ND	ND
Arsenic	mg/l	ND	ND
Barium	mg/l	ND	ND
Beryllium	mg/l	ND	ND
Cadmium	mg/l	ND	ND
Calcium	mg/l	85 01	85 92
Cesium	mg/l	1 00*	ND
Chromium	mg/l	ND	ND
Cobalt	mg/l	ND	ND
Copper	mg/l	3 17	1 78*
Iron	mg/l	ND	0 006*
Lead	mg/l	ND	ND
Lithium	mg/l	12 48	12 82
Magnesium	mg/l	0 636	0 368*
Manganese	mg/l	0 001	0 001
Mercury	mg/l	ND	ND
Molybdenum	mg/l	ND	ND
Nickel	mg/l	ND	ND
Potassium	mg/l	ND	ND
Selenium	mg/l	0 001*	ND
Silver	mg/l	47 36	46 22
Sodium	mg/l	0 382	0 40
Strontium	mg/l	ND	ND
Thallium	mg/l	ND	ND
Tin	mg/l	ND	ND
Vanadium	mg/l	ND	0 032*
Zinc	mg/l	0 027	

TABLE 2-4 (Continued)

**BACKGROUND SURFACE WATER (ROUNDS 1 and 2)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Round 1 (7 samples)**	
		Total	Dissolved
<u>Other</u>			
Total Dissolved Solids	mg/l	271 16	NA
Carbonate	mg/l	ND	NA
Bicarbonate	mg/l	296 97	NA
Chloride	mg/l	106 9	NA
Sulfate	mg/l	48 82	NA
Nitrate	mg/l	2 69	NA
Cyanide	mg/l	ND	NA
pH	- - -	8 69 (6 60)	NA
<u>Radionuclides</u>			
Gross Alpha	pCi/l	7 74	4 38
Gross Beta	pCi/l	9 89	8 80
Uranium 233, 234	pCi/l	1 45	1 40
Uranium 235	pCi/l	0 133	0 133
Uranium 238	pCi/l	0 803	0 957
Strontium 89, 90	pCi/l	2 04	1 398
Plutonium 239, 240	pCi/l	0 018	ND
Americium 241	pCi/l	0 042	0 013
Cesium 137	pCi/l	0 599	0 472
Tritium	pCi/l	258	NA

NA - Not Analyzed

ND - Not Detected

() - Tolerance Interval Lower Limit for Two-Sided Parameter

* - Maximum Detected Value

** - At Stations SU-104 and SU-80, most total and a few dissolved constituents were uncharacteristically high relative to the other data. To be conservative, these data are not included in computation of the tolerance interval.

TABLE 2-5
BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
<u>Total Metals</u>		
Aluminum	mg/kg	24789
Antimony	mg/kg	ND
Arsenic	mg/kg	13 0*
Barium	mg/kg	182*
Beryllium	mg/kg	ND
Cadmium	mg/kg	ND
Calcium	mg/kg	72551
Cesium	mg/kg	ND
Chromium	mg/kg	43 38
Cobalt	mg/kg	ND
Copper	mg/kg	22 0*
Iron	mg/kg	28308
Lead	mg/kg	39 502
Lithium	mg/kg	ND
Magnesium	mg/kg	4110*
Manganese	mg/kg	372 20
Mercury	mg/kg	ND
Molybdenum	mg/kg	ND
Nickel	mg/kg	29 9*
Potassium	mg/kg	ND
Selenium	mg/kg	ND
Silver	mg/kg	6 8*
Sodium	mg/kg	ND
Strontium	mg/kg	175*
Thallium	mg/kg	ND
Tin	mg/kg	ND
Vanadium	mg/kg	50 2*
Zinc	mg/kg	92 688
<u>Other</u>		
Nitrate	mg/kg	ND
pH	----	9 03 (8 77)
<u>Total Radionuclides</u>		
Gross Alpha	pCi/g	60
Gross Beta	pCi/g	50
Uranium 233, 234	pCi/g	1 669
Uranium 235	pCi/g	0 176
Uranium 238	pCi/g	1 755
Strontium 89, 90	pCi/g	1 390
Plutonium 239, 240	pCi/g	0 096
Americium 241	pCi/g	0 029
Cesium 137	pCi/g	1 578
Tritium	pCi/g	0 408

ND	-	Not Detected
*	-	Maximum Detected Value
()	-	Tolerance Interval Lower Limit for Two-Sided Parameter

TABLE 2-6

**BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
Total Metals					
Aluminum	mg/kg	25312	21663	13495	10300*
Antimony	mg/kg	ND	ND	16 2*	ND
Arsenic	mg/kg	15 86	7 7	15 05	3 6*
Barium	mg/kg	155 8	345 8	240 1	165*
Beryllium	mg/kg	11 27	17 75	11 8	2 2*
Cadmium	mg/kg	3 2*	1 8*	ND	ND
Calcium	mg/kg	43079	20811	10183	5940*
Cesium	mg/kg	ND	274*	ND	ND
Chromium	mg/kg	37 9	26 8	16 57	10 7*
Cobalt	mg/kg	18 2*	15 9*	29 7*	20 5*
Copper	mg/kg	20 03	26 7	30 62	19 6*
Iron	mg/kg	22916	29991	41295	12300*
Lead	mg/kg	18 04	26 4	34 5	13 4*
Lithium	mg/kg	44.4	32 1	33 37	7 0*
Magnesium	mg/kg	4425	6151	4896	2520*
Manganese	mg/kg	422.9	545.1	656	305*
Mercury	mg/kg	0 58*	0 44*	0 35*	0 27*
Molybdenum	mg/kg	38 65	32 78	33.68	11 2*
Nickel	mg/kg	43 27	35 4	56 95	14 3*
Potassium	mg/kg	3336	2789	1400*	ND
Selenium	mg/kg	ND	ND	ND	ND
Silver	mg/kg	40 9*	33 5*	18 7*	12 7*
Sodium	mg/kg	ND	3680*	ND	ND
Strontium	mg/kg	226*	111 1	144 42	69 2*
Thallium	mg/kg	ND	ND	ND	ND
Tin	mg/kg	338*	441*	274*	268*
Vanadium	mg/kg	54 67	58 2	47 7	22 2*
Zinc	mg/kg	52 64	98 1	106 7	79 9*

Sheet 1 of 2

TABLE 2-6 (Continued)

**BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
<u>Other</u>					
Sulfide	mg/kg	13*	5*	5*	2*
Nitrate	mg/kg	4 3*	4 274	2 0*	1 9*
pH	-	9 64 (6 06)	9 48 (6 96)	10 14 (7 04)	9 2* (8 0)**
<u>Total Radionuclides</u>					
Gross Alpha	pCi/g	37 108	51 710	52 302	37
Gross Beta	pCi/g	36 886	35 135	35 743	29
Uranium 233, 234	pCi/g	1 491	1 759	1 985	0 8
Uranium 235	pCi/g	0 087	0 169	0 258	0 1
Uranium 238	pCi/g	1 353	1 675	1 643	1 0
Strontium 89, 90	pCi/g	0 768	0 776	0 766	0 4
Plutonium 239, 240	pCi/g	0 017	0 023	0 020	0 01
Americium 241	pCi/g	0 018	NR	NR	NR
Cesium 137	pCi/g	0 082	0 113	MD	0 0
Tritium	pCi/g	0 410	0 299	0 322	0 39

ND - Not Detected
 NR - Data Not Received
 * - Maximum Detected Value
 ** - Minimum Detected Value
 () - Tolerance Interval Lower Limit for Two-Sided Parameter

tolerance interval, this yields conservative interpretation of the site data. It is also noted that the upper limits of the tolerance intervals are similar in magnitude to the maximum concentration observed for the data set.

2.3.2 Borehole Samples

The Phase I RI for OU No. 2 focused on source characterization of preliminarily identified past waste disposal sites (IHSSs). Samples were taken from boreholes drilled into and adjacent to known IHSS locations and analyzed for the parameters listed in Table 2-7. Boreholes were drilled into several IHSSs to the extent practical. However, boreholes were not drilled into sites still containing wastes (the trenches) or radionuclide contamination (903 Pad) because of potential health hazards to field workers and the potential for release of waste constituents to the environment. Figure 2-1 shows Phase I RI borehole locations, and analytical soil sampling results are presented in Appendix A.

The majority of the metals analyzed from subsurface materials at OU No. 2 were below background levels. Those elements which did exceed background are discussed on a site-by-site basis in the subsequent sections.

Plutonium (Pu) and americium (Am) are the principal radionuclide contaminants exhibiting elevated concentrations in surficial soils. Because many of the pedologic samples were mixed into large composites, the Phase I RI data do not rule out the presence of radionuclides other than plutonium and americium. Cesium-137 (Cs-137), tritium (H³), and uranium (U) were detected, albeit at near-background concentrations and in fewer than ten samples. The Phase I RI results are consistent with a recent aerial radiological survey (EG&G, 1989). The radioactivity detected in that survey was associated with known radioactive material storage and handling areas, and was attributed to plutonium, americium, and a uranium decay product. The survey indicated elevated americium in borehole samples at the 903 Pad Lip Site. The cesium-137 activity was at a level consistent with global fallout and not enriched in the Plant area. Planned Phase II sampling activities will aid in evaluating the elevated plutonium and americium concentrations in surface soils and in boreholes.

The following sections summarize available subsurface soil sampling results for the 903 Pad, Mound, and East Trenches Areas.

2.3.2.1 903 Pad Area

903 Drum Storage Site and 903 Pad Lip Site (IHSS Ref Nos. 112 and 155)

The 903 Pad Drum Storage and Lip Sites are considered together here because of the proximity of associated boreholes (BH22-87, BH23-87, BH24-87, BH29-87, and BH30-87).

TABLE 2-7
PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

METALS

Hazardous Substances List - Metals

Aluminum
 Antimony
 Arsenic
 Barium
 Beryllium
 Cadmium
 Calcium
 Chromium
 Cobalt
 Copper
 Iron
 Lead
 Magnesium
 Manganese
 Mercury
 Nickel
 Potassium
 Selenium
 Silver
 Sodium
 Thallium
 Tin
 Vanadium
 Zinc

Other Metals

Chromium (hexavalent)
 Chromium (trivalent)
 Lithium
 Strontium

ORGANICS

Hazardous Substances List -- Volatiles

Chloromethane
 Bromomethane
 Vinyl Chloride
 Chloroethane
 Methylene Chloride
 Acetone
 Carbon Disulfide
 1,1-Dichloroethene
 1,1 Dichloroethane
 trans-1,2-Dichloroethene
 Chloroform
 1,2-Dichloroethane
 2-Butanone
 1,1,1-Trichloroethane
 Carbon Tetrachloride
 Vinyl Acetate
 Bromodichloromethane
 1,1,2,2-Tetrachloroethane
 1,2-Dichloropropane
 trans-1,3 Dichloropropene
 Trichloroethene
 Dibromochloromethane
 1,1,2 Trichloroethane
 Benzene
 cis-1,3 Dichloropropene

TABLE 2-7 (Continued)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List - Volatiles (Continued)

2-Chloroethyl Vinyl Ether
Bromoform
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene
Toluene
Chlorobenzene
Ethyl Benzene
Styrene
Total Xylenes

Hazardous Substances List -- Semi-Volatiles

N-Nitrosodimethylamine
Phenol
Aniline
bis(2-Chloroethyl)ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl Alcohol
1,2-Dichlorobenzene
2-Methylphenol
bis(2-Chloroisopropyl)ether
4-Methylphenol
N-Nitroso-Dipropylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Benzoic Acid
bis(2-Chloroethoxy)methane
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-methylphenol(para-chloro-meta-cresol)
2-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethyl Phthalate
Acenaphthylene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4 Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diethylphthalate
4-Chlorophenyl Phenyl ether
Fluorene
4-Nitroaniline
4,6 Dinitro-2-methylphenol

TABLE 2-7 (Continued)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List -- Semi-Volatiles (Continued)

N-nitrosodiphenylamine
4-Bromophenyl Phenyl ether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butylphthalate
Fluoranthene
Benzidine
Pyrene
Butyl Benzyl Phthalate
3,3'-Dichlorobenzidine
Benzo(a)anthracene
bis(2-ethylhexyl)phthalate
Chrysene
Di-n-octyl Phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenz(a,h)anthracene
Benzo(g,h,i)perylene

Hazardous Substances List -- Pesticides/PCBS

alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Heptachlor
Aldrin
Heptachlor Epoxide
Endosulfan I
Dieldrin
4,4'-DDE
Endrin
Endosulfan II
4,4'-DDD
Endrin Aldehyde
Endosulfan Sulfate
4,4'-DDT
Endrin Ketone
Methoxychlor
Chlordane
Toxaphene
AROCOLOR-1016
AROCOLOR-1221
AROCOLOR-1232
AROCOLOR 1242
AROCOLOR 1248
AROCOLOR-1254
AROCOLOR 1260

Other Organics
Oil and Grease

TABLE 2-7 (Continued)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

RADIONUCLIDES

Gross Alpha
Gross Beta
Uranium-233+234, 235 and 238
Americium-241
Plutonium-239+240
Strontium-89+90
Cesium-137
Tritium

OTHER

pH

Pre-Phase I RI 903 Pad Subsurface Radionuclide Investigations

Prior to the emplacement of the asphalt cover at the 903 Pad, a plutonium surface survey was conducted in 1968 subsequent to drum removal (Owen, 1968). The results of this survey are presented in Figure 2-7. This survey indicates widespread contamination throughout the 903 Drum Storage Site. However, the highest survey values occur beneath the western half of the pad where drums were stored and Building 903 was located.

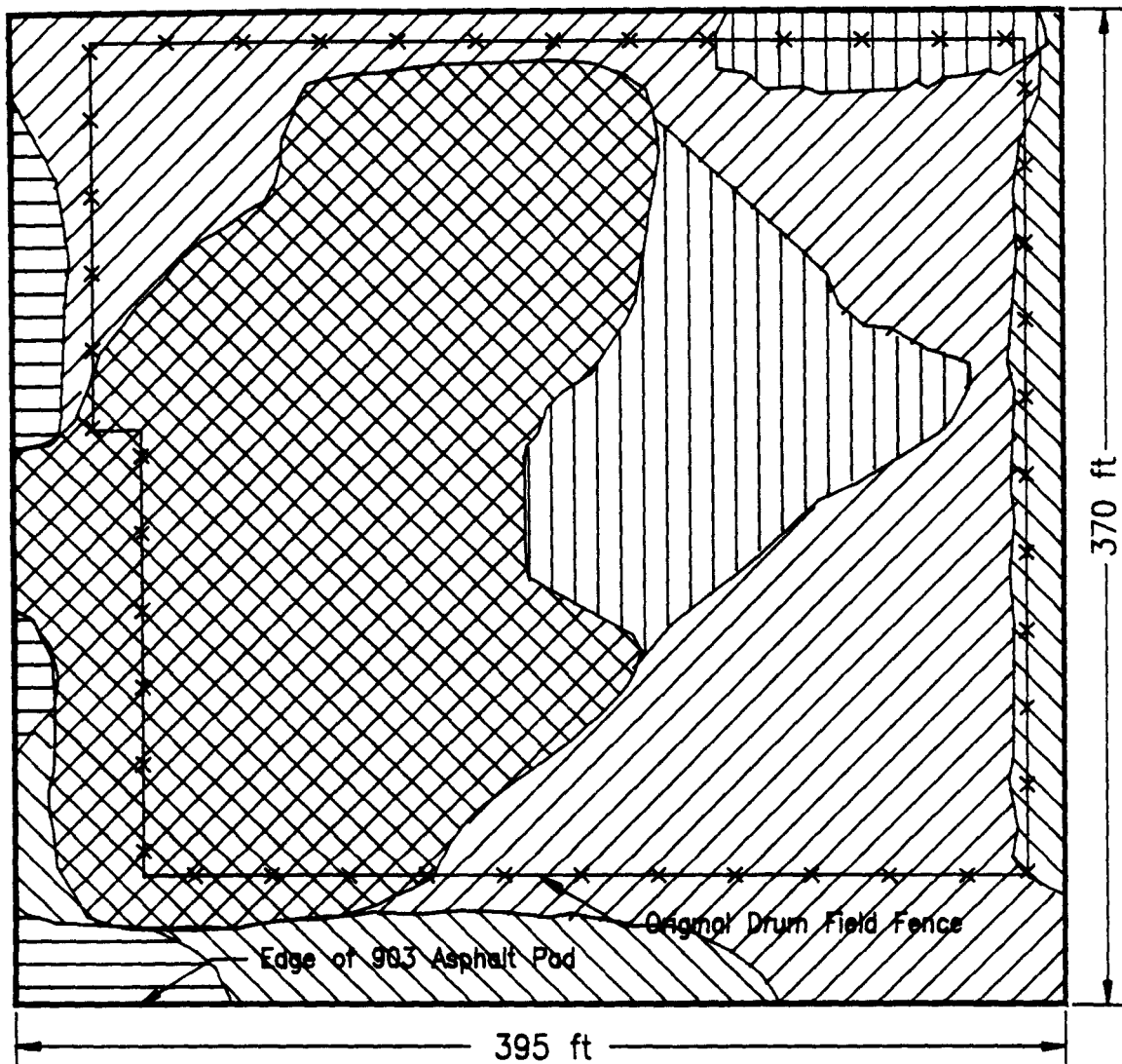
After the emplacement of the asphalt cover, the soils beneath the 903 Pad were sampled in two sampling events for a total of ten excavations. The purpose of both sampling events was characterization of plutonium and uranium concentrations beneath the Pad; other contaminants were not described. The excavation locations are shown in Figure 2-8.

In the earlier of the two sampling events (Seed, et al., 1971), four excavation sites (Figure 2-8) were located on the basis of a gross gamma survey on the asphalt cover. Four two- to four-square-foot holes were hand dug to various depths. The total mass of plutonium yielded from excavations SW and NC were approximately 10 milligrams (mg) and 0.2 to 0.3 mg, respectively. Approximately 25 kg and 6 kg of depleted uranium were recovered from excavations No. 14 and No. 17, respectively. (Depleted uranium is the uranium remaining after the uranium-235 isotope is separated from natural uranium during the gaseous diffusion enrichment process.) Reportedly, no sample contained both plutonium and uranium. Two conclusions are drawn from this study pertinent to waste characterization. First, no evidence was found of radionuclides moving upward from the original ground level into the fill material. Second, at all four locations activity extended no more than one inch into a clay layer which was found 4 to 15 inches below the original ground surface. Table 2-8 presents a summary of the results.






In the later sampling event (Navratil, et al., 1979), six soil samples (Table 2-9) were taken from beneath the 903 Pad. These soil samples were examined to determine the extent and distribution of plutonium and americium.

The average plutonium and americium concentrations reported for the six samples are shown in Table 2-9. Pertinent conclusions drawn from this study are:

- Plutonium and americium are associated with smaller soil fractions.
- An estimated 18,000 tons of contaminated soil underlies the asphalt pad.
- Tests conducted on 903 Pad soil indicate that wet screening is effective in reducing plutonium and americium soil contamination (Navratil, et al., 1979).



EXPLANATION

	less than 0.006 mg/m ²		0.10 to 0.30 mg/m ²
	0.006 to 0.024 mg/m ²		0.30 to 6.0 mg/m ²
	0.025 to 0.10 mg/m ²		

This survey was conducted in 1968, prior to the placement of fill and asphalt containment cover. No correction has been made for penetration into soil. Results are relative.

1 mg = 16.22 pCi

Modified after Owen (1968)



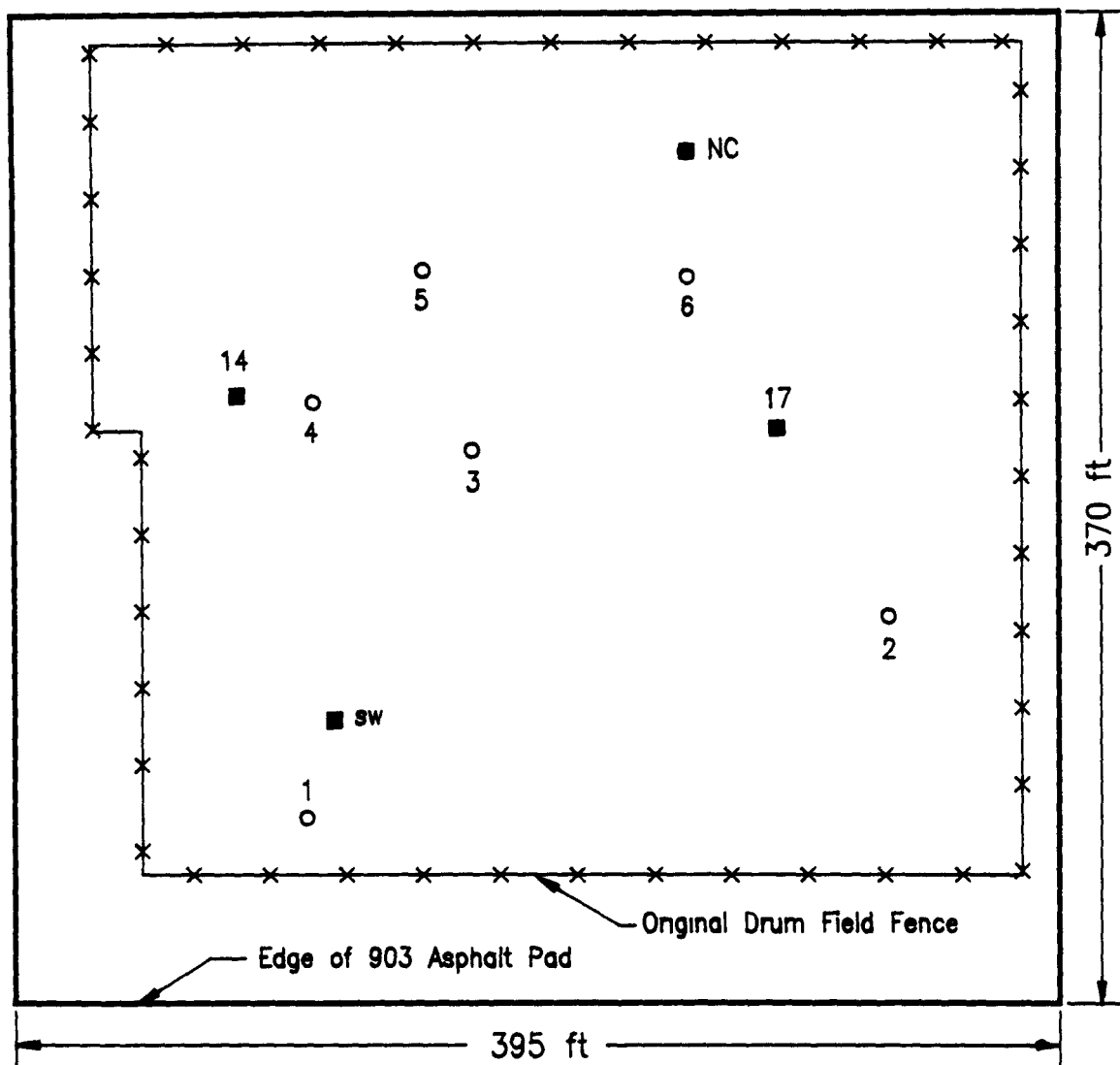
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

RESULTS OF 1968 PLUTONIUM
SURFACE SURVEY AT 903 DRUM
STORAGE SITE

FIGURE 2-7

February, 1991



EXPLANATION

- Sample reported in Seed et al (1971)
- Sample reported in Navratil et al (1979)
- 3 Sample Identifier (See text)

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

LOCATION OF SAMPLES FROM
BENEATH THE 903 PAD

Modified after figure appended to Navratil et al (1979)

FIGURE 2-8

February, 1991

TABLE 2-8

SUMMARY OF RESULTS REPORTED BY SEED, ET AL. (1971)

Hole	Gamma Activity Thru Asphalt (cpm)	Maximum Gamma Reading in Hole (cpm)	Maximum α Reading in Hole (dpm)	Active Material	Where Activity First Detected	Vertical Thickness Activity Layer (inches) Below Original Ground Surface
No 14*	55,000	3×10^4	5,000	Depleted Uranium	Original Ground Layer	6-8
SW	16,000	<16,000	20,000	Plutonium	Original Ground Layer	4-6
No 17	35,000	2×10^4	5,000	Depleted Uranium	Original Ground Layer	1-2
NC	16,000	20,000	1,000	Plutonium	Original Ground Layer	<1

Table modified after Seed, et al (1971) Based on wet chemical analysis

- * This hole was identified as No 32 in original table, however, review of text indicates this was mislabeled and should be hole No 14 (no hole 32 was excavated)

cpm = counts per minute

dpm = disintegrations per minute

TABLE 2-9

SUMMARY OF RESULTS FOR SOIL SAMPLING BENEATH THE 903 PAD

Sample	Radionuclide Content					Sampling Depth from Top of Pad inches
	Pu-239 dpm/g	pCi/g	Am-241 dpm/g	pCi/g	cm ^a	
1	940	427	620	282	46	18
2	1,400	636	1,100	500	61	24
3	8,000	3,636	1,000	455	56	22
4	45,000	20,455	4,200	1,909	66	26
5	14,000	6,364	4,100	1,864	61	24
6	17,000	7,727	5,000	2,273	61	24

Table modified from Navratil, et al (1979)

dpm/g = disintegrations per minute per gram

pCi/g = picoCuries per gram

cm = centimeters

* The sampling depth shows the soil removal depth required to reach soil readings ≤ 250 dpm/g

In summary, plutonium and americium are present beneath the 903 Pad and appear to be restricted to shallow depths below the original ground surface. The distribution of other contaminants in the soils beneath the 903 Pad, however, has not been investigated.

903 Pad and Lip Sites Phase I RI Soil Investigation Results

Hazardous Substances List (HSL) volatile organics were below detection limits in boreholes surrounding the 903 Pad with the exception of bis(2-ethylhexyl) phthalate. Acetone and methylene chloride were reported but are suspected laboratory artifacts as indicated by contaminated laboratory blanks. However, volatile organics are present in ground water at the site and are expected to be present in subsurface materials directly beneath the 903 Pad. Based on borehole sampling results, the extent of volatile organic soil contamination at the 903 Drum Storage Site appears to be confined to the area immediately beneath and adjacent to the pad. Additional boreholes will be drilled through and immediately adjacent to the pad during the Phase II RFI/RI to validate this conclusion.

The Rocky Flats Alluvium near the 903 Pad and Lip Sites contains barium (Ba), cadmium (Cd), calcium (Ca), mercury (Hg), manganese (Mn), antimony (Sb), and zinc (Zn) above background. Of those elements, only manganese was reported above background in more than two samples and by more than a factor of two above the tolerance limit [maximum manganese - 1,080 milligrams per kilogram (mg/kg) in BH23-87]. The isolated occurrence of detectable mercury in colluvium is notable for its very high value (114 mg/kg in BH29-87).

Fewer analytes exceeded background in the deeper units below IHSSs 112 and 155. Cadmium reached 3.8 and 4.0 mg/kg in claystone, and the major ions calcium and aluminum (Al) exceeded background by less than 10% of the tolerance level. Sandstone in BH29-87 exhibited arsenic (As), cadmium, and mercury slightly above background, and iron (Fe), lead (Pb), and vanadium (V) above background by larger margins.

The Phase I RI results provide evidence of plutonium and americium contamination of surface soils. Plutonium and americium are significantly elevated in the 0 to 1 foot composite interval of BH30-87 [plutonium - 180 pCi/kg, americium - 22 pCi/kg], and less so in BH22-87 and BH23-87.

Based on results of a borehole sampling program (Rockwell International, 1987a), it appears that soil within the 903 Pad Lip Site is contaminated with plutonium, americium, and phthalates. Radionuclide contamination (plutonium and americium) is apparently limited to surficial soils, however, this conclusion will be tested during the Phase II RFI/RI.

Trench T-2 Site and Reactive Metal Destruction Site (IHSS Ref Nos 109 and 110)

Boreholes BH25-87 through BH28-87 are grouped here to jointly characterize the Trench T-2 and Reactive Metal Destruction Sites. Volatile and semi-volatile organics were detected just south of Trench T-2 in borehole BH25-87, maximum concentrations of detected compounds were 17,000 micrograms per kilogram ($\mu\text{g/kg}$) of trichloroethene (TCE), 640 $\mu\text{g/kg}$ of toluene, 10,000 $\mu\text{g/kg}$ of PCE, 250 $\mu\text{g/kg}$ of 1,1,1-trichloroethane (1,1,1-TCA), 1,900 $\mu\text{g/kg}$ of bis(2-ethylhexyl) phthalate, 780 $\mu\text{g/kg}$ of ethylbenzene, 3,300 $\mu\text{g/kg}$ of total xylenes, and 1,100 $\mu\text{g/kg}$ of acetone (also detected in the blank). Chloroform (CHCl_3) and 2-butanone were estimated at concentrations below the detection limit in two samples each. Solvent contamination was also found at the eastern corner of Reactive Metal Destruction Site in BH28-87. PCE at 210 $\mu\text{g/kg}$, carbon tetrachloride (CCl_4) at 100 $\mu\text{g/kg}$, bis(2-ethylhexyl) phthalate (3,400 $\mu\text{g/kg}$), and carbon disulfide at 58 $\mu\text{g/kg}$ were all detected below the water table in BH28-87. Additional soil samples will be collected from this site during the Phase II RFI/RI to fully characterize the extent of soil contamination.

Numerous samples contained arsenic and cadmium above background in the vicinity of Trench T-2 and the Reactive Metal Destruction Site. Boreholes near T-2, BH25-87 through BH27-87, contained above-background arsenic and cadmium in both colluvium and claystone, reaching a maximum of 20 mg/kg arsenic in claystone at BH25-87 and 5.4 mg/kg cadmium in colluvium at BH27-87. Only one sample showed above-background barium, but the margin above background was very large (1,899 mg/kg in BH25-87).

Calcium and potassium (K) exceeded background, but the margins of those major soil ions above tolerance levels were ten percent or less. The sole occurrences of above-background nickel (Ni) (36.1 mg/kg in BH25-87) and chromium (Cr) (17 mg/kg in BH27-87) were within one mg/kg of the respective tolerance limits.

Plutonium and americium were elevated above background in surficial materials near Trench T-2 (BH25-87, BH26-87, BH27-87), and in surficial and bedrock materials near the Reactive Metal Destruction Site (BH28-87). Additional planned surficial soil and soil profile sampling will characterize the radionuclide distribution more thoroughly.

2.3.2.2 Mound Area

Mound, Oil Burn Pit, and Trench T-1 Sites (IHSS Ref Nos 113, 153 and 108)

Boreholes BH33-87 through BH38-87 are discussed together here to represent soils in the vicinity of the Mound, Oil Burn Pit, and Trench T-1 Sites.

No volatile organic contamination was found in boreholes BH37-87 and BH38-87 at the Mound Site, but HSL organics were present closer to Trench T-1 and the Oil Burn Pit [acetone, methylene chloride, 1,2-dichloroethane (1,2-DCA), N-nitrosodiphenylamine, di-n-butyl phthalate, and bis(2-ethylhexyl) phthalate]. The detected volatiles were all estimated at concentrations below the detection limit or were present in the associated laboratory blanks at concentrations within a factor of two of the concentration in the sample (not reportable following CLP protocol). Of the semi-volatiles listed above, only bis(2-ethylhexyl)phthalate was found at non-estimated concentrations, and it was only slightly above the detection limits. There is inadequate evidence to demonstrate significant organic contamination of soils in the vicinity of IHSSs 108 and 158, however, additional soil samples will be collected in this area during the Phase II RFI/RI.

Major soil cations, calcium, magnesium, sodium, aluminum, and iron all occurred well above background in alluvium of the Mound Area. Calcium was enriched by more than a factor of ten in BH34-38. Copper (Cu) and vanadium were above background in BH34-87, and cadmium occurred above background in BH33-87. Selenium (Se) was above background in BH38-87 alluvium.

Major ions were less elevated in the claystone and sandstone than in upper units. Calcium and manganese were above tolerance levels by a small margin in only one sample each in BH33-87 and BH37-87.

Arsenic and cadmium were above background in both lithologic units although the margins above background were small. Barium was above background in claystone and lead was above background in sandstone. Potassium was the only major element above background in the sandstone (maximum of 1,400 mg/kg in BH45-87).

Plutonium and americium were elevated in composited pedologic samples adjacent to Trench T-1 (boreholes BH35-87 and BH36-87). Plutonium was detected at 1.5 ± 0.2 pCi/g, and americium was detected at 0.30 ± 0.13 pCi/g in the 0 to 12 foot composite sample from borehole BH35-87. Plutonium was also detected at 0.53 ± 0.16 pCi/g in borehole BH36-87 (0 to 5 foot composite sample). Since radionuclide contamination is limited to soil samples which include the ground surface, wind dispersal of plutonium and americium from the 903 Drum Storage Site is the likely source of these contaminants. This hypothesis will be addressed in the draft RFI/RI Report.

Additional soil sampling of the surface materials will be performed in the Mound Area to identify possible impacts of radionuclide contamination resuspended from the 903 Drum Storage Site. Based on review of historical air photos, the Mound Site location was revised westward during preparation of the Phase I RI report. Additional boreholes are needed in the revised IHSS location.

Pallet Burn Site (IHSS Ref No 154)

Soil organic contamination is apparent at IHSS 154. Maximum organic compound levels in borehole BH31-87 were 580 $\mu\text{g/kg}$ of bis(2-ethylhexyl) phthalate, 32 $\mu\text{g/kg}$ of 1,2-DCA, 110 $\mu\text{g/kg}$ of acetone, and 20 $\mu\text{g/kg}$ of PCE. Maximum organic compound concentrations in borehole BH32-87 were 310 $\mu\text{g/kg}$ bis(2-ethylhexyl) phthalate, 29 $\mu\text{g/kg}$ of 1,2-DCA, and 170 $\mu\text{g/kg}$ of acetone. No other organic contaminants were detected, and no metals were reported above background in BH31-87 and BH32-87. Soil sampling is needed to evaluate the depth and extent of the plutonium in soils. Furthermore, review of aerial photographs and historical documents during the Phase I RI resulted in revision of the Pallet Burn Site location as discussed in Section 2.0. Additional soil samples will therefore be collected from a boring in the possible eastern location of the Pallet Burn Site during Phase II activities.

2.3.2.3 East Trenches Area

Trenches T-3, T-4, T-10, and T-11 (IHSS Ref Nos 110, 111.1, 111.7, and 111.8)

Characterization of the northern East Trenches (T-3, T-4, T-10, and T-11) is based on soil sampling results from boreholes BH39-87 through BH46-87.

Three of the seven boreholes near Trenches T-3, T-4, T-10 and T-11 (BH39-87 through BH46-87) exhibited volatile organics above detection limits. Maximum concentrations of 1,1,1-TCA were 130 $\mu\text{g/kg}$ in BH43-87, 180 $\mu\text{g/kg}$ in BH45-87, and 190 $\mu\text{g/kg}$ in BH46-87. Numerous occurrences of acetone, 2-butanone, and methylene chloride ranged up to several hundred $\mu\text{g/kg}$. In BH39-87 through BH43-87 the acetone results did not have associated laboratory blank contamination and therefore may reflect actual contamination. N-nitrosodiphenylamine was present at estimated concentrations below 100 $\mu\text{g/kg}$.

Several occurrences of bis (2-ethylhexyl) phthalate were found in samples from boreholes at Trenches T-3, T-4, T-10, and T-11. The maximum concentration of 880 $\mu\text{g/kg}$ occurred in BH45-87 (0 to 9.5 foot interval). In addition, four detects for di-n-butyl phthalate are found in the analytical data, however, all were estimated at concentrations below the detection limit, and two of these detected were also present in the associated laboratory blanks (Appendix A).

Calcium was the only major ion in alluvium that was present above background. Its concentration in BH41-87, BH43-87 and BH45-87 ranged between 50,000 and 120,000 mg/kg, well above the tolerance limit of 43,079 mg/kg. All of the boreholes contained up to three trace elements above background except BH44-87. Maximum values were arsenic - 37 mg/kg in BH39-87, cadmium - 6.2 mg/kg in BH39-87, manganese - 58 mg/kg in BH42-87, zinc - 55 mg/kg in BH41-87, and chromium - 58 mg/kg in BH43-87.

In the underlying claystone, sodium was the only major ion above background (maximum of 1,400 mg/kg in 39-87) Boreholes BH40-87, BH42-87, and BH44-87 had no elements above background, whereas BH39-87, BH41-87, BH43-87, BH45-87, and BH46-87 each had a few elements above background Maximum values were arsenic - 25 mg/kg in BH39-87, cadmium - 6.2 mg/kg in BH46-87, barium - 413 mg/kg in BH39-87, manganese - 3,540 mg/kg in BH45-87, vanadium - 60 mg/kg in BH45-87, and zinc - 124 mg/kg in BH46-87

Potassium was the only elevated major element in the sandstone (maximum 1,400 mg/kg in BH45-87), and BH40-87, BH41-87, BH43-87, and BH46-87 had no metals above background A subset of arsenic, barium, cadmium, chromium, iron, manganese, nickel, lead, and vanadium were elevated in each of boreholes BH49-87, BH42-87, BH44-87, and BH45-87

Plutonium was elevated in the surface sample from BH39-87 (0.82 ± 0.12 pCi/g) Additional surficial soil sampling is necessary within this group of trenches to characterize surficial radionuclide contamination

Trenches T-5 through T-9 (IHSS Ref Nos 111.2 through 111.6)

Characterization of the southern East Trenches (T-5 through T-9) is based on soil sampling results from boreholes BH47-87 through BH54-87

Volatile organic contaminants (including acetone and methylene chloride), bis(2-ethylhexyl) phthalate, and N-nitrosodiphenylamine are present in alluvium and claystone in the vicinity of the southern trenches Most of these occurrences are associated with contaminated laboratory blanks, but occasionally substantial concentrations were reported without a corresponding occurrence in the blanks BH47-87, BH49-87, BH50-87, BH52-87, and BH54-87 contain 1,2-DCA (maximum 110 $\mu\text{g/kg}$), TCE (maximum 150 $\mu\text{g/kg}$), PCE (maximum 62 $\mu\text{g/kg}$), and toluene (30 $\mu\text{g/kg}$) Total xylenes (BH54-87, 2.0 to 4.0 foot interval) and 1,1,1-TCA (BH47-87, 8.0 to 9.0 foot interval) were reported at a concentration below the detection limit

Major ions, calcium, magnesium, iron, and potassium were present above background in alluvium near Trenches T-5 through T-9 Only calcium was significantly elevated in more than one borehole (BH47-87, BH48-87, BH52-87, BH53-87, BH55-87, and BH56-87)

Only BH49-87 had no trace elements above background In the other boreholes, arsenic, cadmium and lead were above background in a total of eight samples (maximum arsenic - 30.8 mg/kg in BH54-87, cadmium - 5.6 mg/kg in BH51-87, and lead - 45.6 mg/kg in BH51-87)

Arsenic and cadmium were the only elevated metals in the sandstone beneath T-5 through T-9, and they each exceeded background by only 0.2 mg/kg and in only one sample

Plutonium was detected in the majority of the uppermost soil samples (maximum was 6.0 ± 0.2 pCi/g in BH52-87, 0 to 9.5 foot interval), and in only two subsurface samples (0.98 ± 0.24 pCi/g, 2 to 3.5 foot interval, and 0.14 ± 0.12 pCi/g, 6 to 7.8 foot interval in BH53-87). Americium was detected only in BH52-87 (0.14 ± 0.10 pCi/g, 0 to 9.5 foot interval) and BH53-87 (0.53 ± 0.20 pCi/g, 0 to 18.8 foot interval) surface composites.

2.3.3 Ground Water

Ground-water samples from the 903 Pad, Mound, and East Trenches Areas were analyzed for the parameters listed in Table 2-10. The following discussion of volatile organics, metals, and inorganics focuses on results for the second quarter of 1989. These are the most recent data pertaining to the same season for which the background data are available. However, the discussion of 1989 site-specific radionuclide data relies on first quarter results because complete second quarter site-specific data are unavailable.

Site-specific results are compared to the upper limit of the tolerance interval when available. Maximum detected values are used for comparison where there are insufficient data to calculate tolerance intervals. This condition resulted from either an insufficient number of samples or an insufficient number of detectable concentrations for a given analyte.

Appendix B presents all the ground-water quality data for OU No. 2 wells since remedial investigation sampling began in late 1986 through second quarter 1989 (same data set as was used in the December 1989 submittal). Quarterly ground-water sampling is ongoing at OU No. 2. These longer term data are consistent with the findings in second quarter 1989 unless otherwise noted below. Data value qualifiers are presented in the appendices and on the tables in the following sections. A "J" or an "E" next to an analyte concentration reflects that the concentration is estimated below and above the detection limit, respectively.

2.3.3.1 Volatile Organic Contamination

Carbon tetrachloride, PCE, and TCE are the primary volatile organic contaminants in the unconfined ground-water flow system. Figures 2-9 through 2-11 show isopleths for these compounds in the second quarter 1989 for both unconfined alluvial and bedrock wells. Table 2-11 presents all volatile organics above detection limits in the unconfined ground-water system. Additional monitoring wells have been proposed for the 903 Pad, Mound, and East trenches areas to define the extent of volatile organics in alluvial ground water and to characterize alluvial ground-water flow. The purpose and location of each proposed well are presented in Section 5.1.1.

TABLE 2-10

**PHASE I RI
GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS**

FIELD PARAMETERS

pH
Specific Conductance
Temperature
Dissolved Oxygen

INDICATORS

Total Dissolved Solids
Total Suspended Solids

METALS

Hazardous Substances List - Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Tin
Vanadium
Zinc

Other Metals

Chromium (hexavalent)
Lithium
Strontium

ANIONS

Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate

ORGANICS

Oil and Grease
Hazardous Substances List - Volatiles
Chloromethane
Bromomethane
Vinyl Chloride
Chloroethane
Methylene Chloride
Acetone
Carbon Disulfide
1,1-Dichloroethene
1,1-Dichloroethane
trans-1,2-Dichloroethene
Chloroform

TABLE 2-10 (Continued)

GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

ORGANICS

Hazardous Substances List Volatiles (Continued)

1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon Tetrachloride
Vinyl Acetate
Bromodichloromethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
cis-1,3-Dichloropropene
2-Chloroethyl Vinyl Ether
Bromoform
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene
Toluene
Chlorobenzene
Ethyl Benzene
Styrene
Total Xylenes

RADIONUCLIDES

Gross Alpha
Gross Beta
Uranium-233+234, 235, and 238
Americium-241
Plutonium-239+240
Strontium-90
Cesium-137
Tritium

- * For surface water samples only
- ** Dissolved metals for ground-water samples, total and dissolved metals for surface water samples
- *** Ground-water samples from the first quarter of 1987, and all surface water samples were analyzed for 9 of the HSL volatiles. These volatiles are the chlorinated solvents historically detected in the ground water and are as follows: PCE, TCE, 1,1-DCE, 1,2-DCA, t-1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, CCl₄, and CHCl₃. Condition resulted from either an insufficient number of samples or an insufficient number of detectable concentrations for a given analyte.

TABLE 2-11

**VOLATILE ORGANIC COMPOUNDS DETECTED IN THE
UPPER HYDROSTRATIGRAPHIC UNIT GROUND WATER
SECOND QUARTER 1989**

[illegible]

TABLE 2-11 (Continued)

**VOLATILE ORGANIC COMPOUNDS DETECTED IN THE
UPPER HYDROSTRATIGRAPHIC GROUND WATER
SECOND QUARTER 1989**

Matrix	Well	Date Sampled	Carbon chloride (ug/L)	Tetra- chloro- ethene (ug/L)	Trichloro- ethene (ug/L)	Chloro- form (ug/L)	Methylene chloride (ug/L)	1,1-Di- chloro- ethene (ug/L)	1,1-Di- chloro- ethene (ug/L)	Vinyl chloride (ug/L)	Acetone (ug/L)	Carbon Disulfide (ug/L)	Total-1,2- Dichloro- ethene (ug/L)	Toluene (ug/L)
Weathered Claystone	1 71	5/01/89	690J	69	230	200			5J					
	2-71	5/01/89		8	440	7		8						
	1-74	5/03/89		45,000	1,800									
	3 74	5/08/89	1,100	50	25	11J								
Weathered Sandstone	62-86	4/17/89									2JB			
	9-87	5/01/89												
	11-87	5/02/89	Dry											
	12-87	5/02/89	Dry											
	14-87	4/24/89	160J	4J	68	16								
	23-87	5/03/89		74R										
	25-87	5/08/89	290	840	120	5J			22J					2J
	36-87	5/08/89	610	350E	12,000	290E								

J - Value estimated below detection limit
 E - Value estimated
 R - Value rejected by data validation
 B - Compound also detected in associated blank

Carbon Tetrachloride

Carbon tetrachloride occurs in ground-water monitoring wells east, southeast, and northeast of the 903 Pad Area (Figure 2-9). Of the downgradient wells in this area, 1-71 and 15-87 show the highest levels of CCl_4 [690J and 1,100J micrograms per liter ($\mu\text{g}/\ell$)] (These relatively high concentrations of CCl_4 are flagged "J" because the measurement of the undiluted samples exceeded the range of the standard curve, and the laboratory diluted samples were less than the range of the standard curve. Although this compromises the precision of the data, these results indicate that significant CCl_4 contamination exists). The northern East Trenches may be a second source of CCl_4 , for the downgradient concentrations (in wells 36-87 and 42-86) are greater than the upgradient concentrations (in wells 17-87 and 25-87).

The data from repeated samplings corroborate the second quarter 1989 findings, with CCl_4 concentrations of several hundred to a few thousand $\mu\text{g}/\ell$ in the majority of samples from wells 42-86, 15-87, 17-87, 1-71, 3-74, 11-87, 14-87, 25-87, and 36-87. Other wells had high but isolated CCl_4 readings (for example, 2,292 $\mu\text{g}/\ell$ in 39-86), low but consistent readings (in wells 29-87 and 12-87) less than 100 $\mu\text{g}/\ell$, and one low occurrence in well 35-87 (12 mg/ℓ). These data demonstrate that CCl_4 has penetrated all sampled geologic units except unweathered sandstone. Although CCl_4 was not detected in the Mound Area at well 1-74, the existing well network is not sufficient to define in detail the CCl_4 plume.

Tetrachloroethene

The Mound Area appears to be the primary source of PCE within the study area (Figure 2-10) as well 1-74 contained 45,000 $\mu\text{g}/\ell$ PCE. A plume of PCE with concentrations greater than 100 $\mu\text{g}/\ell$ extends east and southeast (downgradient) from the Mound Area to at least well 36-87. The extent of this plume is not well defined.

PCE was detected in wells southeast (downgradient) of the 903 Pad and Trench T-2 (2-71, 15-87, and 1-71), although the concentrations were lower than in the Mound Area wells. An estimated concentration of 8J $\mu\text{g}/\ell$ at well 64-86 is the only PCE occurrence outside the limits defined by the wells listed above. This low and isolated result does not provide adequate evidence of PCE contamination at well 64-86. Additional monitoring wells and further sampling are required to delineate the extent of PCE contamination in this vicinity.

Nearly all of the wells that contained PCE in second quarter 1989 exhibited that contaminant throughout the historical samplings. PCE was reported as high as 528,000 $\mu\text{g}/\ell$ in well 1-74. The earlier sampling also suggests that the PCE plume may extend farther than shown on Figure 2-10, for occasional samples from wells

39-86, 41-86, 32-87, and 29-87 had PCE concentrations above detection limit. Historical sporadic occurrences of PCE in unweathered sandstone (wells 40-86, 18-87, and 20-87) also may indicate more extensive contamination than implied by second quarter 1989 data alone.

Trichloroethene

The distribution of TCE (Figure 2-11) indicates that all three RI areas are sources of this volatile organic. TCE in wells 1-71, 2-71, 14-87, and 15-87 suggests the upgradient 903 Drum Storage Site, and possibly Trench T-2 and the Reactive Metal Destruction Site, as potential sources. Similarly, TCE in wells 1-74, 17-87, and 35-86 suggests the Mound Area as a source, and TCE downgradient of Trenches T-3 and T-4 also indicates these East Trenches as potential sources. Well 36-87 within the latter area exhibited the highest concentration (12,000 $\mu\text{g}/\ell$).

The 1987-89 data are consistent with results shown in Figure 2-11, exhibiting detectable TCE in nearly all samplings of the wells listed above. Furthermore, four wells which were not explicitly listed for 1989 did contain TCE at several previous samplings (39-86, 32-87, 11-87, and 12-87). Isolated occurrences of TCE, together with the PCE data for unweathered sandstone wells 40-86, 18-87, and 20-87, suggest that even these bedrock units may be contaminated by volatile organics.

Other Volatile Organic Compounds

Indication of other volatile organic contamination in ground water by second quarter 1989 data are confirmed by the more comprehensive 1987-89 results. Vinyl chloride was present during six sampling events at well 35-86 northwest of the Mound Area in concentrations between 400 and 1,000 $\mu\text{g}/\ell$. 1,1-dichloroethene (1,1-DCE) appeared consistently in wells 35-86 and 1-71, and occasionally in wells 2-71, 1-74, and 36-87. The highest 1,1-DCE result was 1,044 $\mu\text{g}/\ell$ in well 36-87. 1,1-dichloroethane (1,1-DCA) appeared as frequently but in lower concentrations than 1,1-DCE in wells 35-86 and 2-71.

Chloroform (CHCl_3) occurred in the majority of samples from wells 42-86, 15-87, 17-87, 2-71, 11-87, 14-87, and 36-87, commonly in association with other volatile organics. The CHCl_3 concentrations were typically over 100 $\mu\text{g}/\ell$, and reached as high as 5,427 $\mu\text{g}/\ell$ in 36-87. CHCl_3 is also reported in two unweathered sandstone wells, 28-87 and 30-87, but these are isolated instances at low concentrations in the absence of other organics. Additional data are required to assess the significance of these values.

Two wells at OU No. 2 contained 1,1,1-TCA at times in the past (11-87 and 36-87). The highest concentration was 1,472 $\mu\text{g}/\ell$ at 36-87.

Methylene chloride and acetone were 119 and 38 $\mu\text{g}/\ell$, respectively, at well 36-87. The relatively high concentration of these constituents, together with their association with several other organics in well 36-87, suggest that they are ground-water contaminants in the sandstone unit. However, in other upgradient or surrounding wells, numerous other reports of methylene chloride and acetone are associated with their occurrence in laboratory blanks, and/or their concentrations are very near the detection limits. Such conditions apply to samples from wells 41-86, 17-87, 27-87, 32-87, 35-86, 2-71, 14-87, 20-87, and 31-87, and do not reliably indicate ground-water contamination with these volatiles. Further sampling and analysis is necessary to resolve if methylene chloride and acetone are present at well 36-87.

2 3 3 2 Inorganic Contamination

Major Ions

Major ions and total dissolved solids (TDS) are somewhat elevated above background throughout and downgradient of the 903 Pad, Mound, and East Trenches Areas (Tables 2-12A and 2-13A through F). Tables 12A through C tabulate inorganic, dissolved metal, and dissolved radiochemistry concentrations, respectively, that exceeded background values in ground water during the second quarter of 1989. Tables 13A through F, 14A through F, and 15A through F list the maxima and frequency of inorganic, dissolved metal and dissolved radiochemistry concentrations, respectively, exceeding background values in ground water detected during sampling in 1987 through 1989. Background figures presented for comparison (Tables 2-12A and 2-13A through F) to all previously collected data may not represent background for quarters other than the second quarter of 1989. Therefore this table serves as a qualitative comparison only. Total dissolved solids typically ranged between 400 and 1,000 milligrams per liter (mg/ℓ), chloride was generally 30-100 mg/ℓ , nitrate was 2-10 mg/ℓ , and most sulfate concentrations were between 10 and 100 mg/ℓ in the second quarter of 1989. In general, major cations were accordingly elevated. The highest concentrations of major ions are in well 29-87 southeast of the 903 Pad as discussed below, although TDS at the northernmost well (35-87) was also elevated above background.

Major ions in 29-87, a well completed in colluvium southeast of the 903 Pad, were notably higher than other shallow ground-water wells upgradient and closer to the 903 Pad (Table 12). (TDS - 3,219 mg/ℓ , chloride - 819 mg/ℓ , sulfate - 891 mg/ℓ , calcium - 279 mg/ℓ , sodium - 353 mg/ℓ , and magnesium - 105 mg/ℓ). The conditions at well 29-87 suggest that the ground-water chemistry there may be strongly influenced by evaporation and associated accumulation of salts. It may be, in effect, in a "saline seep" zone (Miller, et al, 1980). The South Interceptor Ditch is very close to well 29-87, when it recharges local ground water it carries SID salts (in relatively dilute form) and mobilizes salts as it passes through soils (typical regional soils have not been leached of all naturally occurring salts). Subsequent repetitive seasonal evaporation of ground water at

TABLE 2-12A

**INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER
SECOND QUARTER 1989**

Area	Well	T.D.S.	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
ROCKY FLATS ALLUVIUM	BACKGROUND->	352	15 6	2 98	45 1	436	ND	0036*
	33-86	DRY						
	39-86	NSS						
	41-86	482	40 0	7 89	59 6		NR	NR
	42-86	476	49 5	4 39			NR	NR
	43-86	DRY						
	10-87	DRY						
	15-87	NSS	37 1				NR	NR
	17-87	405						
	19-87	DRY						
COLLOVIUM	BACKGROUND->	520*	20*	0 18*	86*	470*	ND	ND
	63-86	DRY						
	67-86	DRY						
	29-87	3219	819	74	891	719	NR	NR
	44-87	DRY						
	BACKGROUND->	947	40 3	0 69*	150	719	ND	ND
	35-86	990	99 2			768	NR	NR
	36-86	DRY						
	37-86	NSS	76	NR	290		NR	NR
	64-86	DRY						
VALLEY FILL ALLUVIUM	BACKGROUND->	320*	11*	0 58*	44*	400*	ND	0036*
	1 71	NSS	16 1	4 99			NR	
	2 71	397	24 1	6 03			NR	NR
	1-74	NSS						
	3-74	NSS						
	BACKGROUND->	170*	15*	1 6*	16*	140*	ND	ND
	62-86	277	29 1	2 27	52 3	184	6 93	NR
	11-87	DRY						
	12-87	DRY						
	280	421	32 0	1 73	47 2	141	15 9	NR
WEATHERED CLAYSTONE	BACKGROUND->	482	82 6	2 44	18 6	259	NR	NR
	23-87	482	41 1	7 11	27 9	281	NR	NR
	25-87	486	38 3	7 95	25 0	281	NR	NR
	35-87							
	BACKGROUND->	1761	607	0 61	950	412	49	ND
	34-86							
	40-86							
	18-87							
	20-87	NSS		1 33			NR	NR
	22-87	NSS		2 02			NR	NR
UNWEATHERED SANDSTONE	BACKGROUND->							
	34-86							
	40-86							
	18-87							
	20-87	NSS					3 14	NR
	22-87	NSS						
	28-87							
	30-87							
	31-87						15 2	NR
	34-87	NSS					NR	NR

BACKGROUND: upper tolerance limit or maximum concentration detected in background.
 NSS = insufficient sample for analysis
 U = Detection Limit
 ND = Not detected
 NR = analysis not performed

TABLE 2-12B

**DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER
SECOND QUARTER 1989**

Area	Well	Al	Sb	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
ROCKY FLATS ALLUVIUM	BACKGROUND->	ND	ND	ND	ND	ND	85	ND	ND	266*	ND	ND	5.79*	365	0.136	0.432*	7.73*	ND	ND	13.4	159*	ND	0.141*
	33-86	DRY																					
	39-86						112						12.1							18.9	55		
	41-86						125						17.1							21.3	66		
	42-86	DRY					154		05				13.5							17.8	57		
COLLUVIUM	BACKGROUND->	ND	ND	ND	ND	ND	77*	ND	ND	ND	ND	ND	172*	0.88*	ND	ND	ND	ND	ND	98.7*	ND	ND	ND
	63-86	DRY																					
	67-86	DRY					279		018				105		0.38	0.42		388		353	3.94		11
	29-87	DRY																					
	44-87	DRY																					
VALLEY FILL ALLUVIUM	BACKGROUND->	ND	ND	ND	ND	ND	138	ND	ND	0.94*	ND	ND	0.28	0.69*	ND	ND	ND	0.11*	ND	88	ND	ND	0.21*
	35-86	04J					143													193	88		0.29
	36-86	DRY																					
	37-86	NSS																					
	38-86	NSS																					
WEATHERED CLAYSTONE	BACKGROUND->	ND	ND	ND	ND	ND	73.4*	ND	ND	ND	ND	ND	45.3*	0.13*	0.15*		1.7	ND	ND	36.9*	ND	ND	107*
	1-71	03B					88																
	2-71	NSS																					
	1-74	035J																					
	3-74	NSS																					
WEATHERED SANDSTONE	BACKGROUND->	ND	ND	ND	ND	ND	65.7*	0.12*	ND	ND	ND	ND	9.41*	0.15*	0.15*		1.35J	ND	ND	25.6*	ND	ND	ND
	62-86	02J					83.3	0.34	005J				10.0					0.49	0.04	51.6	41		
	9-87	DRY																					
	11-87	DRY																					
	12-87	DRY																					
UNWEATHERED SANDSTONE	BACKGROUND->	327*	ND	0.19*	ND	ND	64.6	ND	ND	ND	ND	ND	ND	0.18*	112*		21.9*	0.41*	ND	599	45*	ND	56
	34-86		NR				224			2.17													
	40-86																						
	16-87	NSS																					
	18-87	NSS																					
UNWEATHERED SANDSTONE	BACKGROUND->	ND	ND	ND	ND	ND	64.6	ND	ND	ND	ND	ND	ND	0.18*	112*		21.9*	0.41*	ND	599	45*	ND	56
	34-86		NR				224			2.17													
	40-86																						
	16-87	NSS																					
	18-87	NSS																					

BACKGROUND upper tolerance limit or maximum concentration detected in background* U = Detection limit MD = Not Detected
 NSS = insufficient sample for analysis J = present below detection limit NR = analysis not performed A = data acceptable with qualifications
 Note No detects above background for any well for Be Cs Co Hg Tl

TABLE 2-12C

**DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER
SECOND QUARTER 1989**

Area	Well	Alpha	Beta	U233,U234	U235	U238	Pu239,Pu240	Am241
ROCKY FLATS ALLUVIUM	BACKGROUND >	12	15	1 6	0	1 2	01	0
	33-86	DRY						
	39-86	NSS						
	41-86							
	42-86							
	43-86	DRY						
	10-87	DRY						
	15-87	DRY						
	17-87	DRY						
	19-87	DRY						
COLLUVIUM	BACKGROUND >	27*	12*	11*	0 3*	7 7*	0*	0*
	63-86	DRY						
	29-87	DRY						
	44-87	DRY						
	BACKGROUND >	14	19	6 5	0 2	5 1	01	0 01
	35-86	DRY						
	36-86							
	37-86							
	64-86							
	65-86							
WEATHERED CLAYSTONE	BACKGROUND >	12*	7*	5 8*	2*	3 2	03	0
	1-71	NSS						
	2-71	NSS						
	1-74	NSS						
	3-74	DRY						
	BACKGROUND >	7*	2*	1 1*	0*	0 6*	01*	01*
	62-86	DRY						
	1-87	DRY						
	11-87	DRY						
	12-87	DRY						
WEATHERED SANDSTONE	BACKGROUND >	13*	15*	13	1	3 4	0	0 02
	34-86	NSS						
	46-86	NSS						
	16-87	NSS						
	18-87	NSS						
	20-87	NSS						
	22-87	NSS						
	26-87	NSS						
	30-87	NSS						
	31-87	NSS						
UNWEATHERED SANDSTONE	BACKGROUND >	13*	15*	13	1	3 4	0	0 02
	34-86	NSS						
	46-86	NSS						
	16-87	NSS						
	18-87	NSS						
	20-87	NSS						
	22-87	NSS						
	26-87	NSS						
	30-87	NSS						
	31-87	NSS						

BACKGROUND: upper tolerance limit or maximum concentration detected in background*
 NSS = insufficient sample for analysis
 U = Detection Limit
 ND = Not detected
 NR = analysis not performed

TABLE 2-13A

**ROCKY FLATS ALLUVIUM
MAXIMA AND FREQUENCY OF INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	T.D.S	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
33-86	352 DRY	15 6 ---	2 98 ---	45 1 ---	436 ---	ND ---	0038* ---
39-86	452 12/12	41 0 12/12	7 2 12/12	66 3 11/12		NR	0/3
41-86	1806 10/10	947 10/10	13 6 9/10	78 5 10/10		NR	0/3
42-86	526 10/11	57 0 11/11	7 2 10/11	70 0 1/11		NR	0/3
43 86	409 2/3	51 0 3/3	7 9 3/3			NR	0/3
10 87	DRY						
15 87	487 3/3	58 8 3/3	9 1 3/3			NR	
17-87	466 7/7	275 7/7		83 0 3/7		NR	0/0
19 87	DRY						
24 87	DRY						
26-87	DRY						
27 87	439 4/4	34 6 4/4	9 92 3/3	77 3 4/4		NR	NR
32-87	630 6/6	40 7 6/6	15 5 6/6	113 6/6		NR	NR
33-87	DRY						
35 87	DRY						

*Max of background conc range
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling
N55 - Insufficient Sample for Analysis
MD - Not Detected
NR - Not Reported
U - Detection Limit
J - Present below detection limit
FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-13B

**VALLEY FILL ALLUVIUM
MAXIMA AND FREQUENCY OF INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	T.D S.	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
35-86	947	40.3	0.69*	150	719	ND	ND
	BACKGROUND->						
	MAXIMUM FREQUENCY	106 11/11		3/11			
36-86	DRY						
37-86	DRY						
64-86							
	MAXIMUM FREQUENCY	54.1 3/4	1.28 2/4	180 3/4	0/1	0/1	
65-86							
	MAXIMUM FREQUENCY	64.0 5/5		190 1/5	0/4	0/4	
66-86							
	MAXIMUM FREQUENCY	51 3/7			0/1	0/3	
21-87	DRY						

*Max. of background conc range NSS - Insufficient Sample for Analysis ND - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no. of values above background / no. of samples analyzed

TABLE 2-13C

COLLUVIUM
MAXIMA AND FREQUENCY OF INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)

Well	T.D.S.	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
63-86	520* DRY	20*	0 18*	86*	470*	ND	ND
67-86	564 3/3	47.2 3/3	4.9 3/3	110 2/3		NR	0/3
29-87	3219 7/7	819 7/7	96 6/7	1157 7/7		NR	NR
44-87	DRY						

BACKGROUND->

*Max of background conc range MSS - Insufficient Sample for Analysis ND - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
 MAXIMUM Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-13D

**WEATHERED CLAYSTONE
MAXIMA AND FREQUENCY OF INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	T.D S.	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
1-71	320*	11*	0 58*	44*	400	ND	0036*
	MAXIMUM FREQUENCY	21 5 14/14	7 3 14/14				0/5
2 71	1627 9/9	573 9/9	5 4 9/9			NR	0/5
1-74	490 9/9	30 5 9/9	9 8 9/9			NR	0/3
3-74	490 7/7	122 6/7	9 6 7/7			NR	0/3

*Max of background conc range MSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-13E

**WEATHERED SANDSTONE
MAXIMA AND FREQUENCY OF INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	T.D.S.	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
	170*	15*	1 6	16*	140*	NO	NO
62-86	326 12/12	102 12/12	7 41 11/12	90 12/12	178 6/12	9 3/3	0/5
9-87	311 8/8		2 96 8/8	56 8 8/8	198 8/8	NR	NR
11 87	654 3/3	92 4 3/3	2 25 3/3	108 3/3	368 3/3	NR	0/2
12-87	641 3/3	57 3/3	1 6 3/3	203 3/3	354 3/3	NR	NR
14 87	661 9/9	32 1 3/9	1 83 9/9	48 8 9/9	530 1/9	505 7/7	0/1
23 87	459 8/8	65 8 8/8	2 98 8/8	70 4 8/8	261 8/8	NR	0/1
25-87	496 9/9	41 1 9/9	8 02 9/9	52 9/9	281 9/9	NR	NR
36-87	486 7/7	218 7/7	8 06 7/7	43 5 7/7	281 6/7	NR	NR

*Max of background conc range NSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-13F

**UNWEATHERED SANDSTONE
MAXIMA AND FREQUENCY OF INORGANIC CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	T.D.S.	Chloride	Nitrate/ Nitrite	Sulfate	Bicarbonate	Carbonate	Cyanide
34-86	1761	607	0.61	950	412	49	ND
	BACKGROUND->						
	MAXIMUM FREQUENCY			1084 4/11		NR	0/4
40-86		19.9 1/6	6.62 5/5			NR	0/2
16-87			2.02 4/8			5.5 1/1	0/1
18-87	0/1	0/1	0/1	0/1	0/1	NR	NR
20-87	0/1	0/1	0/1	0/1	0/1	35.9 1/1	NR
22-87						3.14 1/1	NR
28-87						NR	NR
30-87						NR	NR
31-87			3.55 1/7			NR	NR
34-87						21.1 6/6	
45-87						0/1	0/1

*Max of background conc range NSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY no of values above background / no of samples analyzed

TABLE 2-14A

**ROCKY FLATS ALLUVIUM
MAXIMA AND FREQUENCY OF DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Cu	Fe	Pb	Li	Hg	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
	ND	ND	ND	ND	ND	ND	85	ND	ND	266*	ND	ND	ND	5 79*	365	0136*	0432*	7 73*	ND	ND	13 4	159*	ND	141*
39-86	085 6/16			28 13/14			120 13/13					0 10 0/3		13 4 14/16 1/16							18 9 14/16 14/16			
33-86	DRY	1987-1989																						
41-86	07 4/10	04 1/10	23 8/10	004J 2/9	1/9	130 8/10	012 2/10	02 4/10	58 1/10			0 10 0/2		17 8 9/10	85 1/10		075 2/10	8 2 1/10		03 1/10	51 3 9/10	67 9/10	037 1/4	
42-86	2 6 5/14	04 1/14	33 13/14			165 13/14	02 1/14	06 4/14	2 1 9/14			0 10 0/2	0 013 2/11	14 9 13/14	61 9/14		10 4/14			13 1/14	18 1 13/14	57 12/14	039 1/8	
43-86	04 1/3		16 3/3			95 2/3								10 5 3/3		024 1/3				14 2 2/3	43 3/3			
10-87	DRY	1987-1989																						
15-87	05 3/6	019 1/5	19 5/6			134 6/6	038 1/6	01 3/6	05 2/6			10 0/4		11 1 6/6						04 1/6	49 6/6			
17-87	07 4/9		0 16 5/9			117 9/9	01 1/9	42 7/9	05 5/9			10 0/3		13 3 9/9	1 27 1/9		69 9/9			28 5 9/9	60 9/9			2 56 3/7
19-87	DRY	1987-1989																						
24-87	DRY	1987-1989																						
26-87	DRY	1987-1989																						
27-87	05 2/5		12 3/5			95 4/5		008 2/5				NR		15 8 5/5	009 1/5					01 1/5	30 1 5/5	60 5/5		
32-87	04 3/6		20 4/5			129 4/5	04 1/5	22 3/6				10 0/1		19 4 5/6	62 2/6		37 3/6			31 8 5/6	63 5/6	98 4/6		
33-87	DRY	1987-1989																						
35-87	DRY	1987-1989																						

TABLE 2-14B

**VALLEY FILL ALLUVIUM
MAXIMA AND FREQUENCY OF DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Al	Sb	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
	MD	MD	MD	MD	MD	138	MD	MD	94*	MD	28*	26 6	69*	MD	MD	MD	011*	MD	88	MD	MD	021*
35 86	11 4/12	05 2/12	004J 6/11	12 8/12		170 9/12	027 1/12	01 6/12				68 12/12	4 37 11/12			2 3 6/12			210 12/12	96 12/12		04 7/12
36 86	DRY																					
37 86	DRY																					
64-86	043 2/5			11 4/5				034 3/5			1U 0/3		78 1/5	027 2/5	049 2/5	2 4 3/5			167 3/5	70 4/5		
65 86	24 4/10	078 2/10		24 5/10	001 1/6			02 2/10	024 2/6		1U 0/4				053 1/10	2 7 5/10			0 78 7/10			099 6/10
66 86	053 3/7			11 4/7				007 1/7	04 2/7		1U 0/5			10 3/7	1 7 2/7				37 5/7			072 5/7
21 87	NSS																					

COLLOVIUM
MAXIMA AND FREQUENCY OF DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)

Well	Al	Sb	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
63 86	ND	ND	ND	ND	ND	77°	ND	ND	ND	ND	172°	15.3	088°	ND	ND	ND	ND	ND	98.7°	ND	ND	ND
BACKGROUND->																						
67 86	04 2/5	ND	ND	25 5/5	89 3/5	022 1/5	NR	38.1 5/5	17 2/5	016 1/5	1.2 5/5	036 1/5	088 2/5	ND	ND	ND	ND	ND	ND	ND	ND	ND
29 87	09 4/8	12 3/7	07 5/8	358 7/7	03 3/8	84 5/8	136 7/8	39 2/8	08 3/8	1.41 7/8	5.2 4/6	45 5/5	405 7/6	4.95 7/8	2.77 7/8	ND	ND	ND	ND	ND	ND	ND
44 87	DRY																					

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NSS - Insufficient Sample for Analysis
Max of background conc range **MAXIMUM** - Maximum conc above background reported over course of Phase I RI sampling
MD - Not Detected
MR - Not Reported
U - Detection Limit
J - Present below detection limit
FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-14D

**WEATHERED CLAYSTONE
MAXIMA AND FREQUENCY OF DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Al	Sb	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn	
	ND	ND	ND	ND	ND	73	4°	ND	ND	ND	0.31°	45	3°	0.15°	ND	ND	ND	ND	36	9°	ND	ND	107°
1-71																							
	06 4/15	036 3/15	30 13/15	87 7/15	016 2/15	1.23 11/15	02 1/15	03 0/3	16 14/15	05 1/15	2.6 9/15	015 1/15	58 14/15										
2-71																							
	064 4/11	071 1/11	16 10/11	201 6/11	029 3/11	92 9/11	019 1/11	07J 0/3	80 11/11	05 2/11	2.7 6/10	04 10/10	02 1/11	259 11/11	1.61 1/11								
1-74																							
	066 4/11	18 6/11	116 11/11	015 3/11	008 2/11	06 6/11	008 2/11	1 U 0/3	34 3/11	3.8 6/11													
3-74																							
	39 4/8	29 7/8	135 6/8	12 1/8	02 5/8	35 6/8	007 1/8	1 U 0/2	063 1/11	045 1/11	1.0 6/8	40 8/8	36 5/8										

TABLE 2-14E

**WEATHERED SANDSTONE
MAXIMA AND FREQUENCY OF DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Al	Sb	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Tl	Sr	V	Zn	
	NO	NO	NO	NO	NO	65	7°	012°	NO	NO	NO	0106°	9	41°	292°	015°	NO	NO	NO	25	6°	NO	NO	NO
62-86	BACKGROUND->																							
	4 75 12/15	058 1/15	007 1/15	13 8/15	009A 1/12			045 12/15	017 3/15	2 9 9/15	021 2/15	04 1/5	12 4 9/15		10 4/15	44 5 14/15	07 13/15	62 2 15/15			52 15/15	092 5/15		
9-87	05 3/9			12 5/9		103 8/9	2/9	021 2/9	024 2/9	073 4/9	1 U 0/3					5/9	004 1/9				36 8/9	04 5/9		
11-87				13 2/2		117 2/2					07 1/2	29 0 2/2	39 2/2		26 1/2	7 9 2/2	02 2/2	51 3 2/2			96 2/2			
12-87	085 3/4			084 4/4				056 1/4	01 3/4	21 4/4	13 2/3				12 4/4	3 5 4/4					27 4/4	05 2/4		
14-87	1 20 6/12	029 1/12		93 6/12		408 2/12		04 7/12	01 5/12	06 4/12	10 1/6	11 8 1/12			31 7/12	014 7/12		96 2 10/12		7 7 8/12	092 3/12	03 3/12		
23-87	17 3/10			19 6/10		130 10/10		068 1/10	015 1/10	19 5/10	1 0/3	14 4 10/10			056 1/10	4 6 5/10		0 01 1/7		62 10/10	028 1/10	08 5/10		
25-87	2 68 4/9			17 7/9		130 9/9		07 2/9	013 1/9	4 35 6/9				71 2/9	023 1/9	3 9 4/9		38 9/9	0401 1/9					
36-87	068 3/7			22 7/7		123 7/7		02 2/7	01 2/7	03 5/7	1 U 0/1	10 4 3/7	35 7/7		05 2/7	1 85 5/7				43 7/7	037 4/7			

TABLE 2-14F

UNWEATHERED SANDSTONE
MAXIMA AND FREQUENCY OF DISSOLVED METAL CONCENTRATIONS (MG/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)

Well	Al	Sb	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
BACKGROUND-->																						
34-86		327° ND 11 2/11	019° ND 09 9/11	ND 09 9/11	ND 242 11/11	64 242 11/11	ND 017 4/11	ND 012 4/11	ND 2 18 11/11	ND ND	ND 2 1/2	ND 92 11/11	018° ND 14 11/11	112° ND 14 11/11	ND ND	21 9° ND ND	041° ND ND	599 ND	45° ND 3 1 11/11	ND ND	56 ND	
40-86		47 2/5		073 4/4		153 4/4	027 1/4	01 3/5	24 4/5		04 J 0/3	31 3 5/5	54 4/5	10 4/5	05 3/5			03 1/4			1 49 4/4	
16-87				08 6/8			028 3/8	011 2/8	14 5/8		05 J 0/3	5 97 7/8		037 5/8						35 7/8		
18-87		09 1/1		11 1/1				04 1/1	06 1/1			1 1 1/1	12 1/1	029 1/1	066 1/1			01 1/1		11 1/1		
20-87		26 1/1		007 1/1				007 1/1	034 1/1		1 U 0/1	034 1/1		057 1/1						44 1/1	038 1/1	
22-87		05 4/6		06 4/6			012 2/6	018 2/6	04 4/6		1 U 0/1	17 5 6/6	07 6/6	08 5/6						89 6/6	10 1/3	
28-87		27 1/3		09 2/3				05 1/3	18 2/3		1 U 0/1	3 1 2/3	03 1/2	13 2/3						24 2/3		
30-87		08 5/9		04 3/9				07 7/9		009 1/9	1 U 0/3	3 42 7/9		025 1/9			1 1/9			33 8/9		
31-87		26 5/7		019 3/6				014 3/7	17 5/7		1 U 0/1	1 02 5/7		05 4/6						23 6/7		
34-87		12 2/4		007 1/4			012 3/4	013 2/4	97 3/4		22 1/1	64 3/4	15 3/4	036 3/3						2 60 3/4		
45-87		13 4/8		17 6/8		006 1/8		01 3/8	12 5/8		06 J 0/3	13 3 8/8	40 8/8	065 4/4	039 1/8					49 7/8		

TABLE 2-15A

**ROCKY FLATS ALLUVIUM
MAXIMA AND FREQUENCY OF DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Alpha	Beta	U233,U234	U235	U238	Pu239,Pu240	Am241	Tritium
33-86	12 DRY	15	1 6	0	1 2	01	0	309
39-86	26 2/9	32 3/9	2 9 7/7	17 5/7	1 9 7/7			
41-86	19 1/6	85 4/6	3 9 5/5	18 5/5	2 4 5/5			
42-86	215 1/7	144 1/7	2 8 1/6	08 1/6	2 6 1/6	0 18 1/6		560 2/6
43-86								
10-87	DRY							
15-87	46 3/4		2 9 3/4		2 74	0 52 1/4	0 83 1/4	
17-87	18 1/6	18 1/6	5 2 3/5	25 4/4	4 1 3/4			
19-87	DRY							
24-87	DRY							
26-87	DRY							
27-87			4 6 2/2	12 2/2	3 2 2/2			
32-87	78 3/5	61 1/5	4 6 4/4	28 4/4	2 8 4/4		0 1 1/4	
33-87	DRY							
35-87	DRY							

Max of background conc range NSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
 MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-15B

VALLEY FILL ALLUVIUM
MAXIMA AND FREQUENCY OF DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)

Well	Alpha	Beta	U233,U234	U235	U238	Pu239,Pu240	Am241
35-86	14	19	6 5	0 2	5 1	01	0 01
36-86	DRY						
37-86	DRY						
64 86							
65 86							
66 86							
21-87	DRY						

4
2/3

*Max of background conc range NSS - Insufficient Sample for Analysis, MD - Not Detected, NR - Not Reported, U - Detection Limit, J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling, FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-15C

COLLUVIUM
MAXIMA AND FREQUENCY OF DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)

Well	Alpha	Beta	U233, U234	U235	U238	Pu239, Pu240	Am241
63-86	27° DRY	12°	11°	0.3°	7.7°	0°	0°
67-86	MAXIMUM FREQUENCY	49 1/1	16 1/1		25 1/1		
29-87	32 1/6	33 1/6	15 3/3	73 3/3	11 3/3		
44-87	DRY						

Max of background conc range NSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
 MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-15D

**WEATHERED CLAYSTONE
MAXIMA AND FREQUENCY OF DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Alpha	Beta	U233, U234	U235	U238	Pu239, Pu240	Am241	Sr89, Sr90
	12°	7°	5 8°	2°	3 2	03	0	0 1
1 71	BACKGROUND >							
	MAXIMUM FREQUENCY	14 2/6	6 3 1/6	5 1/6	4 1 1/6			
2 71	MAXIMUM FREQUENCY	37 3/4	25 6/6	9 5/5	18 6/6			
1-74	MAXIMUM FREQUENCY							5 0 1/2
3-74	MAXIMUM FREQUENCY	327 3/6	2 4 1/5					

*Max of background conc range NSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-15E

**WEATHERED SANDSTONE
MAXIMA AND FREQUENCY OF DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Alpha	Beta	U233,U234	U235	U238	Pu239,Pu240	Am241
	7°	2°	1 1°	0°	0 6°	01°	01°
62-86	MAXIMUM FREQUENCY 27 1/5	24 1/5	4 3 4/5	3 5/6	9 5 5/6	6 3/6	
9-87	MAXIMUM FREQUENCY 3 3 1/7	3 3 1/7		05 2/3	67 3/3		
11-87	MAXIMUM FREQUENCY 28 1/2		9 6 1/2		6 5 2/2	20+/- 07 1/2	06+/- 05 1/2
12-87	MAXIMUM FREQUENCY 121 4/4	57 4/4	34 3/3	1 7 3/3	28 3/3		
14-87	MAXIMUM FREQUENCY 17 3/7	19 5/7	6 7 2/2	05 1/1	4 3 2/2		
23-87	MAXIMUM FREQUENCY 39 2/7	5 9 3/7	6 7 5/5	14 5/5	4 3 5/5		
25-87	MAXIMUM FREQUENCY 19 1/8	7 4 1/8	3 2 6/6	09 1/5	1 8 5/5		
36-87	MAXIMUM FREQUENCY 17 2/6	23 3/6	2 3 3/4	10 2/4	1 4 3/4		

*Max. of background conc range NSS - Insufficient Sample for Analysis MD - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY - no of values above background / no of samples analyzed

TABLE 2-15F

**UNWEATHERED SANDSTONE
MAXIMA AND FREQUENCY OF DISSOLVED RADIOCHEMISTRY CONCENTRATIONS (PCI/L)
EXCEEDING BACKGROUND IN GROUND WATER (1987-1989)**

Well	Alpha	Beta	U233, U234	U235	U238	Pu239, Pu240	Am241
WELL NUMBER	ALPHA	BETA	U233 U234	U235	U238	Pu239 Pu240	Am241
34-86	13*	15*	13	0.1*	3.4	0	0.02 11+/- 05 1/7
40-86	106 3/3	207 2/3		45 3/3	3.9 3/3		
16-87	48 3/8	16 1/8		21 2/4			
18-87		24 1/1					
20-87		37 1/1	NR	NR	NR		
22-87	22 1/6			18 2/5			11+/- 08 1/5
28-87							
30-87	33 1/7						17+/- 12 1/6
31-87	36 1/6						
34-87		16 1/4		21 1/4			
45-87	32 2/5	113 5/5		12 1/5			

*Max. of background conc range NSS - Insufficient Sample for Analysis ND - Not Detected NR - Not Reported U - Detection Limit J - Present below detection limit
MAXIMUM - Maximum conc above background reported over course of Phase I RI sampling FREQUENCY no. of values above background / no. of samples analyzed

this location would cause accumulation of salts in the local soils, forming a saline reserve which would chemically alter the local ground water. Other upslope, non-saline ground-water sources could have the same effect.

In general, this evaporative concentration effect may explain the elevated TDS southeast of the 903 Pad where surface seeps are abundant, and evaporative mineral deposits in the soils are likely. This is discussed further in Section 2.3.8.

Metals

In the second quarter 1989 data for all the wells at the 903 Pad, Mound and East Trenches Areas, all of the dissolved metals except beryllium, cadmium, cobalt (Co), cesium, and thallium (Tl) exceeded background, and all the wells had some subset of these metals occurring above background concentrations (Table 2-12B). When multiple samplings are accounted for (Table 2-14A through F), it becomes more apparent that only a subset of the analytes repeatedly exceed background and/or exceed background by a wide margin.

Barium and strontium (Sr) exceeded background more consistently than all of the other trace metals, with maximum concentrations of 0.93 mg/L and 7.7 mg/L, respectively (both in well 14-87) (Table 2-14E). The relatively uniform concentrations of barium (0.1-0.2 mg/L) may indicate that the solubility of barium sulfate is controlling the barium concentration. Equilibrium control of barium is typical for natural waters (Hem, 1985), and the observed barium and sulfate concentrations are consistent with the barium sulfate solubility product of 10^{-10} (Sillen and Martell, 1964). Similarly, strontium may be controlled by the solubility of a strontium sulfate mineral in waters where strontium is sufficiently high (Hem, 1985).

Several other trace metals less consistently (with respect to time) and less ubiquitously occurred above background. These include copper, iron, molybdenum, nickel, selenium, vanadium, and zinc. In many instances these elements occur at low concentrations near background so that geochemical phenomena, e.g. adsorption on oxides, ion exchange, and/or biological activity, may control their concentration more so than contaminant releases from sources (if they exist). There are no absolute criteria with which to define such thresholds, but the following discussion focuses on wells which repeatedly exhibit unusually high metal concentrations and/or concentrations consistently above background. Table 2-14A through F provides the maximum metal concentrations and their frequency of occurrence above background.

In the 903 Pad Area, well 29-87 has generally consistent above-background concentrations of copper, nickel, zinc, and selenium. Well 62-86 is noteworthy because of consistently elevated chromium (albeit low concentrations), and well 2-71 is noted for consistently elevated but low concentrations of selenium. In the Mound Area, well 17-87 has high concentrations of copper, nickel, and zinc. In the East Trenches Area, well

42-86 has high iron and manganese, well 32-87 has high copper, nickel and zinc, and well 3-74 has high iron and zinc. In general, antimony, lead, lithium, silver (Ag), mercury, and cobalt exceeded background infrequently and by a very small margin in ground water at the 903 Pad, Mound, and East Trenches Areas.

Radionuclides

All three uranium isotopes were above background at the 903 Pad, Mound and East Trenches Areas in the first quarter of 1989 (Tables 15A through F). Other radionuclides were not present above background in the first quarter of 1989, but there were seven earlier samples that contained plutonium and/or americium above background. Results at wells 15-87 and 11-87 were the most elevated (plutonium - 0.522 ± 0.117 pCi/l and 0.199 ± 0.07 pCi/l, respectively, americium - 0.831 ± 0.148 pCi/l and 0.06 ± 0.05 pCi/l, respectively). Several results showed strontium-89,90 and tritium slightly above background, but these radionuclides were not reported for most of the samples and detection limits were commonly above background. Cesium-137 was not reported. The data for these three radionuclides are inadequate to assess contamination.

Several wells within or downgradient of the 903 Pad Area exhibit uranium-238 in excess of background, with a maximum of 28 ± 2 pCi/l at well 12-87 (in weathered sandstone). Other wells in the 903 Pad Area, 2-71 (in Rocky Flats Alluvium) and 29-87 (in colluvium), showed elevated uranium concentrations in the majority of samplings. Uranium concentrations in downgradient wells 62-86 and 14-87 (in weathered sandstone) and in 1-71 (inferred to be in weathered claystone) are lower than at well 12-87, but they are nevertheless above background. Therefore, the downgradient limit of uranium contamination at the 903 Pad Area is not established. Wells in unweathered sandstone in the vicinity of the pad (16-87, 30-87, and 45-87) contain slightly elevated or no uranium-238 above background (maximum concentration was 1.4 pCi/l in well 45-87), providing inadequate evidence of radionuclide contamination in unweathered bedrock.

Mound Area wells 23-87 (in weathered sandstone) and 17-87 (in Rocky Flats Alluvium) both contained uranium above-background at numerous samplings, whereas wells 1-74 (in weathered claystone) and 35-86 (in valley fill alluvium) did not contain above-background uranium. Uranium concentrations are only slightly above background and therefore do not unequivocally indicate contamination.

Uranium-238 was detected above background in the East Trenches Area in the following wells: 25-87 and 36-87 (in weathered sandstone), and 42-86, 32-87, 41-86, and 39-86 (in Rocky Flats Alluvium). The only well that did not have above background concentrations of uranium in the vicinity of the East Trenches Areas was 3-74 (in weathered claystone). The areal distribution of uranium in this area is not well characterized.

2 3 4 Surface Water

Twenty-six surface water and surface seep samples in the vicinity of the 903 Pad, Mound, and East Trenches Areas were collected during Phase I RI field activities. The following discussion is based on all available data because many seeps or stream stations are dry during some sampling events. Appendix C contains all available data from 1986 through 1990. These data have been summarized (Appendix D) and compared to ARARs (see Section 7.0 for ARAR Identification) because contaminated surface water has been targeted for an Interim Measures/Interim Remedial Action (IM/IRA). The following discussion makes reference to the tables in Appendix D. Total radiochemical and metals data, although presented in the appendix, are not discussed because an assessment methodology that accounts for varying concentrations of suspended solids is still being developed.

A discussion of surface water chemistry for the 903 Pad, Mound, and East Trenches Areas is also one of ground-water chemistry, as several of the surface water samples collected for this investigation are from seeps that represent the surfacing of ground water or water from depressions in which runoff accumulates. In addition, there is frequent interaction of surface water and ground water in the drainages. The seeps and areas of ponded water are located downslope and southeast of the 903 Pad Area, or downslope and north of the Mound Area and East Trenches Area. Surface water flowing in drainages was sampled at stations on the South Interceptor Ditch and Woman Creek just upstream of Pond C-2 and at stations upstream of the B-series ponds on South Walnut Creek. The B-series ponds were not sampled for this investigation, as they will be subsequently investigated as part of another operable unit. Surface water locations are shown on Figure 2-12.

2 3 4 1 Surface Water Stations Southeast of 903 Pad Area

There are several seeps downslope to the southeast of the 903 Pad. Surface water stations established at these seeps in the 903 Pad Lip Area are designated SW-50, SW-51, SW-52, SW-55, SW-57, SW-58, and SW-77. Station SW-50 is closest to the 903 Pad, and SW-57 and SW-52 are south of SW-50. SW-51 and SW-58 are located in a ditch along the road east of SW-50, however, only overland flow of seepage from SW-50, SW-52, and SW-57 will also enter the ditch. Water in the ditch passes under the road south of these locations through a culvert. The discharge of the culvert is SW-55. SW-77, another seep located on the east side of the road, is just north of SW-55. It is noted, therefore, that SW-51, SW-58, and SW-55 are physically connected and likely receive flow from SW-50, SW-52, and SW-57. Farther downgradient stations include seeps at SW-53, SW-62, SW-63, and SW-64, SW-27, SW-30, SW-54, and SW-70 on the SID, and SW-26, SW-28, and SW-29 on Woman Creek.

Data for seeps in the vicinity of the 903 Pad Lip Site (Table D-1) and farther downgradient at SW-53, SW-63, and SW-64 indicate organic contamination. Contaminants in seeps in the vicinity of the 903 Lip Site include 1,1-DCE, 1,2-dichloroethene (1,2-DCE), CCl_4 , TCE, and PCE with concentrations of CCl_4 and TCE exceeding $1,000 \mu\text{g}/\ell$. 1,2 DCE and TCE are occasionally present at SW-53, low concentrations of CCl_4 and TCE ($<20 \mu\text{g}/\ell$) occur at SW-63, and low concentrations of TCE occur at SW-64. Methylene chloride also occasionally occurs in these seeps, but at concentrations near the detection limit, and also frequently occurs in the laboratory blanks. Low and very infrequent concentrations of these and other volatiles occur at seep SW-62, as well as stations along the South Interceptor Ditch and Woman Creek. The data do not provide convincing evidence of impacts at these stations, however, the volatile organic concentrations in the upgradient seeps suggest that a solvent plume within alluvial ground water is migrating to the southeast, which is consistent with the alluvial ground-water flow direction. It is inferred that organic contaminated alluvial ground water approaches the South Interceptor Ditch and Woman Creek.

With respect to inorganic and dissolved radionuclide contamination, there are somewhat elevated concentrations of TDS, major ions, strontium, zinc, and uranium at most of these stations. Surface water at stations along the SID (SW-70, SW-30, SW-54, and SW-27) all have somewhat elevated uranium concentrations (generally less than $10 \text{ pCi}/\ell$ of total uranium). These concentrations are usually above ARAR ($5 \text{ pCi}/\ell$). Although the 903 Pad Area cannot be ruled out as the source of the uranium, the occurrence of elevated uranium as far upgradient as SW-70 suggests the 881 Hillside Area as a potential source. Alluvial ground water at the 881 Hillside contains above-background levels of uranium.

Seeps in the vicinity of the 903 Pad Lip Site (SW-50 and SW-53), had detectable plutonium and/or americium during one event in 1989. The samples contained substantial suspended solids and were not filtered at the time of collection. Total radiochemistry data do indicate notably higher plutonium and americium concentrations in unfiltered samples than in filtered samples, demonstrating that most of the radionuclides are in a particulate form. Since radionuclide soil contamination is documented in this area, the local soils represent the most direct potential source for seep contamination. However, there were traces of plutonium and americium in a few ground-water samples (highest concentrations at wells 15-87 - $0.522 \pm 0.117 \text{ pCi}/\ell$ and $0.031 \pm 0.148 \text{ pCi}/\ell$, respectively), so ground water is also a potential source of radionuclides in seeps, albeit a less significant one. It is noted that plutonium and americium are essentially insoluble but minute quantities can migrate in colloidal form, and colloidal-size particles can pass through $0.45 \mu\text{m}$ filters such as those used in the Phase I RI (Puls and Barcelona, 1989).

Regardless of the transport mode, total plutonium concentrations occur above background at station SW-29 on Woman Creek (range $<\text{MDA} - 0.315 \pm 0.115 \text{ pCi}/\ell$), and dissolved plutonium was just detectable during one sampling event ($0.159 \pm 0.142 \text{ pCi}/\ell$). Dissolved plutonium was also just detectable at station SW-70 on the SID ($0.11 \pm 0.09 \text{ pCi}/\ell$), however, the total plutonium concentration was $0.011 \pm 0.057 \text{ pCi}/\ell$ during this

sampling event, rendering this data questionable. The one datum that exists in the remedial investigation data base indicates total plutonium is not above background in Pond C-2 (dissolved radionuclide data are unavailable).

2 3 4 2 Upper South Walnut Creek

At the Mound Area, station SW-60 is a corrugated metal pipe discharging South Walnut Creek flow which originates to the west of SW-56 (not sampled in 1989). Stations SW-56 and SW-101 are in a ditch that appears to be seepage from the base of the hill to the south. The ditch is not part of the main flow of South Walnut Creek, as the creek is routed beneath this area by a corrugated metal pipe which discharges at SW-60. Water in the ditch eventually discharges to South Walnut Creek through a concrete pipe beneath the PSZ fence. The flow in South Walnut Creek upstream of Pond B-4 is primarily the combined flow from the discharge of these culverts and a seep (SW-59) located at the base of the hill to the south and downstream of the culverts. The seep at SW-59 coincides with the abandoned waste collection pipe (IHSS 142) that joined with the main plant waste discharge line prior to 1983, inside the PSZ. This combined flow is sampled at SW-61 located at the confluence.

The upper reaches of South Walnut Creek as characterized by data for stations SW-56, SW-59, SW-60, SW-61, and SW-101 contain CCl_4 , PCE, and TCE in concentrations in excess of $200 \mu\text{g}/\ell$, with lesser and infrequent concentrations of 1,1-DCE, 1,1-DCA, 1,2-DCE, vinyl chloride, acetone, bromo-dichloromethane, and methylene chloride. These stations also frequently have above ARAR levels of TDS and uranium. The TDS and uranium concentrations are typical of the alluvial ground water in the vicinity of the 903 Pad and Mound Areas. CCl_4 , PCE, TCE, and elevated zinc are also present in the alluvial ground water at the Mound Area.

Stations SW-21 and SW-23 approximately 500 feet farther downstream from the confluence of SW-59, SW-60, and SW-61 do not exhibit the upstream contamination. Although only one datum exists for each station, (August 1986 sampling), CCl_4 ($9 \mu\text{g}/\ell$) was the only volatile organic detected at SW-21, and volatile organics were absent at the further downstream station, SW-23. Although there are no August 1986 data for the upstream stations, the other results suggest the organics have volatilized or were diluted over this reach.

Further surface water (and ground-water) sampling and analysis will be conducted to better define the extent and source of the contamination. However, potential sources outside the Mound Area will be investigated as another operable unit.

2 3 4 3 Seeps at the East Trenches Areas

Of the two seeps at the East Trenches Areas (SW-65 and SW-103), SW-65 has no apparent organic contamination, and SW-103 has the constant presence of CCl_4 at concentrations less than $10 \mu\text{g}/\ell$. Dissolved uranium was also above ARAR at SW-65.

Sampling of both surface water and ground water will continue to better define the extent of surface and ground-water contamination in this area.

2 3 5 Sediments

Sediment stations have been established along the Woman Creek and the South Walnut Creek drainages. As shown on Figure 2-12, stations SED-28, SED-29, and SED-25 are located within the South Interceptor Ditch in the Woman Creek drainage. SED-30 and SED-31 are seeps on the South Interceptor Ditch berm near station SED-29. SED-27 and SED-26 are along Woman Creek just upstream of Pond C-2. Stations SED-11, SED-12, and SED-13 are located along South Walnut Creek. SED-11 is the most upgradient station, SED-12 is just upstream of Pond B-1, and SED-13 is just downstream of Pond B-5.

Data discussed herein are for samples collected in 1989 and are presented in Appendix E.

2 3 5 1 Woman Creek Drainage

Chloromethane was present at SED-29 ($60 \mu\text{g}/\text{kg}$), and CHCl_3 and TCE were reported at SED-31 ($18 \mu\text{g}/\text{kg}$ and $8 \mu\text{g}/\text{kg}$, respectively). Several sediment samples contained methylene chloride and acetone at very low concentrations. These compounds were frequently found in associated blanks. SED-30 contained $220 \mu\text{g}/\text{kg}$ acetone at one sampling, but acetone was also present in the blank for this sample and was undetected in two other sampling events for this station in 1989. Laboratory artifact is suspected for acetone and methylene chloride results in this area. The only other volatile organic compounds detected in the Woman Creek drainage sediment samples were TCE ($8 \mu\text{g}/\text{kg}$) at SED-31 (estimated below detection limits elsewhere) and toluene (estimated below detection limit) at SED-29 and SED-30.

Of the metals, beryllium, lithium, silver, and tin (Sn) were notably elevated above background in the sediment of the SID and Woman Creek. Concentrations of silver are greater than five times the upper limit of the background range (as high as $49.1 \text{ mg}/\text{kg}$) at stations SED-29, SED-30, and SED-25. Beryllium was not detected in the background samples ($< 1.1 \text{ mg}/\text{kg}$) but occurs at concentrations ranging from 3.8 to $15.0 \text{ mg}/\text{kg}$ in all the sediment samples collected from the SID and Woman Creek. Although tin was not above

background (<22.8 mg/kg) at SED-27, SED-28, and SED-31, it occurred in a range from 364 to 1080 mg/kg at stations SED-25, SED-26, SED-29, and SED-30

Plutonium was above background at stations SED-25, SED-26, SED-29, and SED-30, ranging in concentration from 0.3 to 3.3 pCi/g. Contaminated surface soil from the 903 Pad Area, transported by wind, may be the source of this plutonium.

2.3.5.2 South Walnut Creek Drainage

Limited 1989 data exist for the three sediment stations on South Walnut Creek. There are no data for SED-12 and SED-13, and only volatiles, metals, and other inorganics data exist for SED-11 (Appendix E).

At SED-11, CHCl_3 , CCl_4 , TCE, PCE, and acetone were present at 10, 52, 17, 39, and 167 $\mu\text{g/kg}$, respectively. This is consistent with the data for SW-61 which indicate that these are surface water contaminants.

As in the Woman Creek drainage, beryllium, lithium, silver, and tin are elevated in the sediments at SED-11. They occurred at concentrations of 2.5, 7.2, 15.0, and 404 mg/kg, respectively. Zinc, which is a known contaminant of ground water and surface water in this vicinity, was also notably elevated, occurring at a concentration of 735 mg/kg (the upper limit of the background tolerance interval is 93 mg/kg).

Sediment samples were taken in October 1989 at stations along South Walnut Creek as well as Woman Creek and the SID. The resulting data should suffice as confirmatory information regarding the concentrations of volatile organics, metals, other inorganics, and radionuclides in the sediments and will be presented in the RFI/RI report. For the Phase II RFI/RI, physical characteristics of the sediments (background and "downgradient") and the spatial distribution of the metal concentrations will be examined to assess the adequacy of the background sediment geochemical characterization and, thus, whether metals are contaminants in the sediments at the 903 Pad, Mound, and East Trenches Areas.

2.3.6 Air

Results of the continuous radionuclide monitoring program characterizing the air pathway at the Plant are reported in monthly reports and annually in the Annual Environmental Monitoring Reports (e.g., Rockwell International, 1975 through 1983a, 1984, 1985, 1986b, 1987b, 1989d, and EG&G, 1990f). In addition, the air pathway was further characterized by the radioecology and airborne pathway study (Rockwell International, 1986f).

The Radioactive Ambient Air Monitoring Program (RAAMP) consists of 54 high-volume particulate air samplers which operate continuously (Figure 2-13). Twenty-six of the 54 samplers are within or directly adjacent to the Plant security area (on-site samplers) and 14 are located around the property boundary (perimeter samplers). An additional 14 samplers are located in neighboring communities (Figure 2-14).

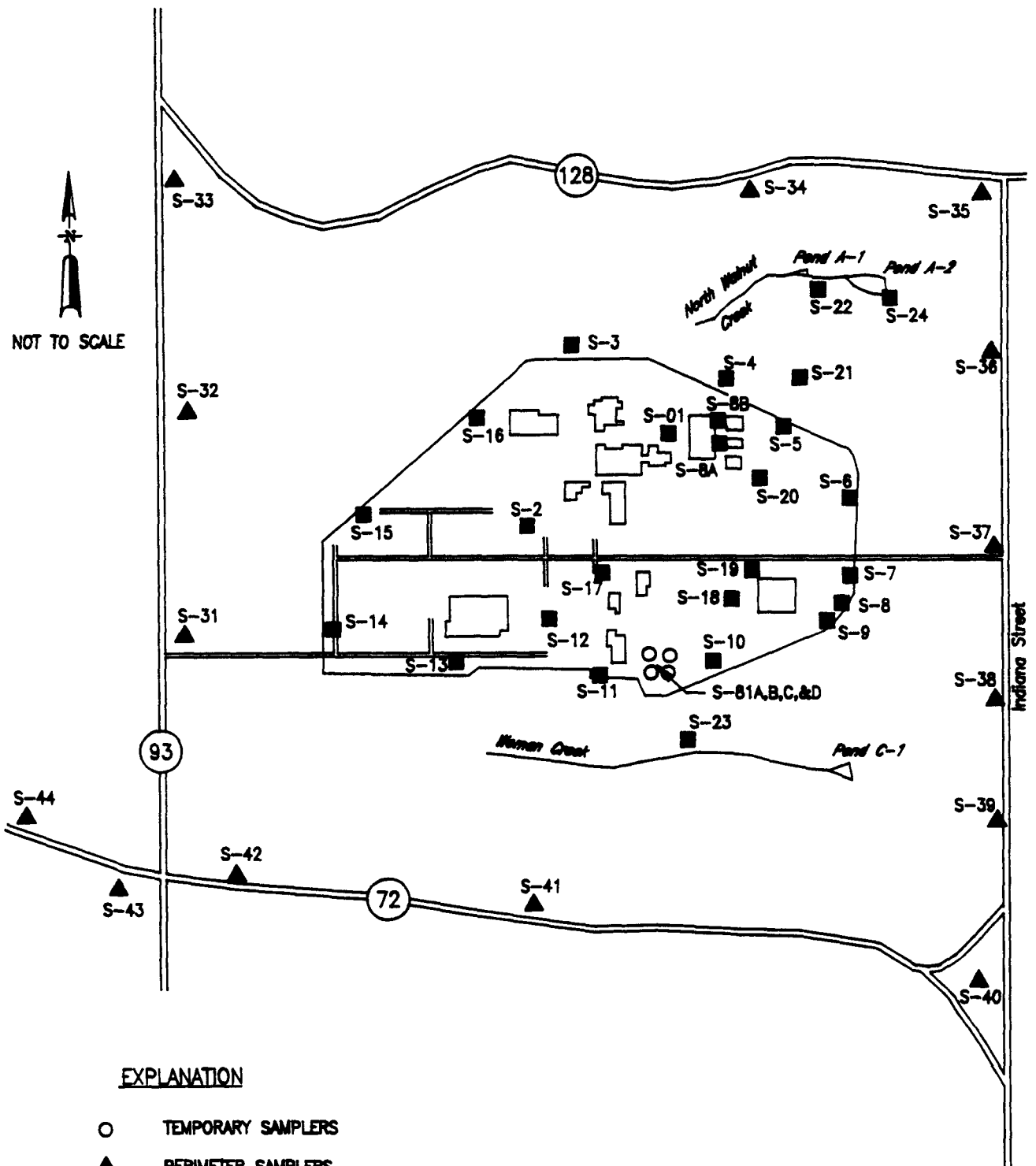
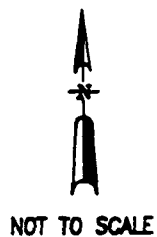
The 903 Pad Area is recognized as one principal source of airborne plutonium contamination at the Plant (Rockwell International, 1975 through 1983a, 1984, 1985, 1986b, 1987b, 1989d, and EG&G, 1990f). Historically, the particulate samplers located immediately east, southeast, and northeast of the 903 Pad, Mound, and East Trenches Areas have shown the highest plutonium concentrations. This finding is corroborated by the results of soil surveys which indicate elevated plutonium concentrations to the east, particularly southeast of the area. However, the RAAMP has found ambient air samples to be well within applicable DOE guidelines for the protection of human health and the environment for all plutonium (Rockwell International, 1989d).

Prior to the Phase I RI activities, personnel trained in industrial hygiene surveyed the 903 Pad Area on March 25, 1987, the Mound Area on April 23, 1987, and the East Trenches Area on April 8, 1987, for the presence of volatile organics in ambient air. The surveys were done with draeger tubes sensitive to PCE and TCE in the parts per million range. These two compounds were chosen since investigations prior to March 1987 had indicated PCE and TCE were the most commonly found contaminants at the 903 Pad, Mound, and East Trenches Areas, and they were also found in higher concentrations than other contaminants. Air sampling was conducted six inches above the ground, at numerous point locations throughout the 903 Pad, Mound, and East Trenches Areas. All values were below detection limits.

Ambient air data analyzed for 1987 do not indicate any unusual effects due to Phase I RI field activities at the 903 Pad, Mound, and East Trenches Areas. An analysis of 1) particulate sampler data from stations near the 903 Pad, Mound, and East Trenches Areas, and 2) real-time volatile organics monitoring, conducted during the summer 1987 field activities, indicates that there were no significant releases of plutonium or volatile organics due to RI field activities. These are verified by the absence of radioactive contamination of either personnel or equipment associated with 903 Pad, Mound, and East Trenches Areas Phase I RI field activities.

High volume air samplers were installed and operated for the duration of the Phase I RI borehole and well drilling activity at the 903 Pad, Mound, and Trench Areas. The samplers were located downwind of each drilling site. At the conclusion of the daily activity, the filters from the air samplers were removed and analyzed for total long lived (TLL) alpha activity. No elevated TLL levels were detected during the Phase I RI.

The RAAMP plutonium data for Plant air sampling stations S-5, S-6, S-7, S-8, S-9, and perimeter air sampling stations S-38, S-39, and S-40 are presented in Table 2-16 for the months of July, August, and September 1987.



EXPLANATION

- TEMPORARY SAMPLERS
- ▲ PERIMETER SAMPLERS
- ON-SITE SAMPLERS

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

LOCATION OF ON-SITE AND
PLANT PERIMETER AMBIENT AIR
SAMPLERS

FIGURE 2-13

February, 1991

TABLE 2-16

RAAMP AIR SAMPLING SITES
PLUTONIUM-239 AND -240 CONCENTRATIONS (pCi/m³)
JULY, AUGUST, AND SEPTEMBER 1987

	S-5	S-6	S-7	S-8	S-9	S-38	S-39	S-40
				<u>JULY 1987 DATA</u>				
LCL*	000064	00018	003735	002666	001644	000005	000001	- 000002
Point	000047	000016	000497	000892	001317	000001	- 0002	- 000002
Estimate	000029	000005	000190	000696	000362	000015	000001	000007
UCL**								
				<u>AUGUST 1987 DATA</u>				
LCL*	000076	000134	004170	003018	001859	000008	000003	000000
Point	000059	000022	000561	000995	001477	000003	000000	000001
Estimate	000038	000010	000218	000776	000405	000018	000003	000010
UCL**								
				<u>SEPTEMBER 1987 DATA</u>				
LCL*	000088	000150	004605	003370	002074	000010	000005	000002
Point	000071	000028	000625	001098	001637	000005	000002	000004
Estimate	000047	000015	000246	000856	000448	000021	000005	000013
UCL**								

LCL* Lower Confidence Level
 UCL** Upper Confidence Level
 DOE Derived Concentration Guide for Plutonium = 0.02 pCi/m³

The perimeter sampling stations in Table 2-16 were selected because they are in predominantly downwind locations from on-site samplers 7,8, and 9. These data cover the period of borehole and well drilling activity at 903 Pad, Mound, and East Trenches Areas. Based on wind rose data for the Plant, these air sampler data have a high probability to indicate releases resulting from drilling and vehicular activity during this period of time.

The monthly averages for plutonium at the perimeter sampling stations (S-38, S-39, S-40) during the site investigation activity are not significantly higher than the historical averages for the same sampling stations. The on-site samplers (S-5, S-6, S-7, S-8, and S-9) have recorded values during site investigation activities below the DOE-derived concentration guide (DCG). The RAAMP samplers show no difference in plutonium concentrations as a result of the drilling activity during the months of July, August, and September 1987.

2.3.7 Biota

The biota at the 903 Pad, Mound and East Trenches Area have been previously studied. A survey was conducted for the Final Environmental Impact Statement, Rocky Flats Plant Site (DOE, 1980), and previous studies were summarized in the Radioecology and Airborne Pathway Data Summary Report (Rockwell International, 1986f). The Radioecology and Airborne Pathway Data Summary Report addresses the plutonium released from the 903 Drum Storage Site and its effects on the immediate environment. Field studies were conducted over several years which compared various biological measurements and pathological data between ecologically similar study areas of widely varying plutonium levels. Soil plutonium concentrations were measured, along with biological measurements such as vegetation community structure and biomass, litter mass, arthropod community structure and biomass, small mammal species occurrence, population density, biomass, reproduction, and physical size of whole carcasses and organs. In addition, pathological examination of small mammals, including x-ray for skeletal sarcomas, microscopy for lung tumors, and necropsy for general pathology and parasite occurrence, were carried out. Results of the studies showed no evidence of ecological impacts attributable to plutonium. Although pathological conditions were found in some rodents, there were no significant pathological differences between control and plutonium-contaminated areas. Other minor differences in biological attributes could not be correlated to plutonium levels.

Aquatic studies, conducted by Colorado State University (CSU), examined phytoplankton, some detritus and small zooplankton uptake of plutonium from the B-series holding ponds. This study showed that an "increase in trophic-level concentration of plutonium did not occur apparently due to a selective mechanism that discriminated against plutonium at this level. This would result in a decreased potential hazard when considering the transfer of plutonium through ingestion routes" (Paine, 1980).

Other aquatic studies revealed that 77 percent of the plutonium associated with crayfish is found in their exoskeleton. Fish flesh and bone from the A- and C-series ponds were never above the minimum detectable activity for plutonium.

2.3.8 Summary of Contamination

The Phase I RI investigations of environmental media lead to the general conclusions that volatile organic and radionuclide contamination exists in soils, surface water, ground water, and sediments around several IHSSs. The distribution and magnitude of the contamination can be better delineated via sampling and analysis planned for the Phase II investigation.

Plutonium and americium are the principal radionuclide contaminants in the surface soils at the 903 Pad, Mound, and East Trenches Areas exhibiting elevated concentrations, however, conclusive evidence ruling out the presence of other radionuclides is not available because of the compositing of soil samples during the Phase I investigation. The majority of the metals in the soil samples were below background levels. There were infrequent instances where the metals concentrations exceeded background by a factor of two above the tolerance intervals. Volatile organic contamination of soils appears to be restricted to the area immediately beneath and adjacent to the 903 Pad. Volatile organics were also detected at the Trench T-2 Site, the East Trenches, and the Pallet Burn Site. The Mound Area does not appear to have volatile organic soil contamination based on the Phase I data.

Trichloroethene, PCE, and CCl_4 are the principal organic contaminants in surface and ground water. Lesser concentrations of other organic compounds occur at numerous sampling sites throughout OU No. 2. Plutonium and americium in surface water samples are other apparent indicators of Plant-derived contamination.

Several metals and other inorganic constituents (including uranium) are also above background in the environmental media, but the data do not permit unambiguous conclusions with regard to contamination. The uncertainty results in part from the absence of clear concentration gradients and from the limited knowledge of the inorganic composition of waste resources. OU No. 2, however, there is considerable circumstantial evidence (listed below) that forms the basis for the hypothesis that evaporative losses at ground-water discharge zones may be causing accumulation of salts (in soils) and associated local changes in water quality. Many factors can cause the near-surface, fluctuating water table conditions which are a prerequisite for such evaporative concentration. Rapid slope changes can be sufficient to induce natural seepage, for example, and enhanced flow along relatively impermeable rock units can form contact seeps. The presence of caliche in the vicinity of OU No. 2 indicates that long-term evaporation is a locally significant hydrogeochemical process. Also, historical changes in the local hydrological regime can cause relatively rapid salt accumulation by

introducing ground water into soils which have not been previously leached. Such "saline seep" formation has been studied extensively (Miller, et al, 1980). At Rocky Flats, constructed ponds and ditches may have raised the water table and caused dissolution of salts from previously unleached or less leached soils. The circumstantial evidence for a local evaporative concentrating process for ground water is as follows:

- Most of the elevated elements are not known constituents of the waste sources in OU No. 2
- The elevated constituents do not exhibit clear gradients away from known IHSSs, or for that matter, clear horizontal or vertical gradients
- The variability in inorganic constituent concentrations is typically very small, and almost always within an order of magnitude
- Some of the major ions do show very pronounced elevation above background, but the highest concentrations of inorganic constituents is in a well which is one of the farthest from the IHSSs (29-87)
- Other parts of the Rocky Flats Plant show similar distributions of major and minor elements and locally very high concentrations of major ions which are not demonstrably derived from IHSSs (wells 5-86 and 6-86). The background characterization may not be adequate because the current data are based on one quarter of sampling, and the well layout was designed without the specific goal of including evaporation-prone zones
- The wells with the high TDS and major ions commonly also have the most elevated metals and uranium. This raises the possibility that, if the salinity is due to some concentrating process other than waste input, some or all of the minor elements may also occur in elevated concentrations. This is consistent with the observation that the uranium in ground water at the 881 Hillside Area is of natural origin based on uranium-234/uranium-238 ratios. The Plant uses depleted uranium which was found to be present only in some surface soils at the 881 Hillside.

No single feature of the data listed above rules out the possibility that some or all of these inorganic constituents do represent contamination. However, when viewed in aggregate, the observations show that it is plausible, perhaps probable, that these elevated inorganic constituents do not reflect contamination. The conceptual model that local concentrations are due to evaporation of shallow ground water generates several hypothesis which will be tested in part with existing data, and tested more thoroughly with data from the OU No. 2 Phase II activities and the ongoing background characterization.

2.4 SITE CONCEPTUAL MODEL

A site conceptual model was developed based on site physical characteristics and the nature and extent of contamination discussed in Sections 2.1 through 2.3. This model is intended to summarize known and suspected sources of contamination, types of contamination, affected media, contaminant migration pathways, and environmental receptors. It will be used to assist in identifying sampling needs and potential remedial alternatives. The site conceptual model is depicted in Figure 2-15.

2 4 1 Contamination Sources and Types

Sources of contamination at the 903 Pad, Mound, and East Trenches Areas include radionuclide-contaminated surface soils (originating at the 903 Pad Area), and subsurface contaminated soil and buried wastes. Plutonium and americium are the principal contaminants of the surface soils. Volatile organics (principally TCE, PCE, and CCl_4) are the most abundant contaminants of subsurface soils. These contaminants originated from historical waste spills and buried wastes. The buried wastes also likely contain plutonium, americium, and depleted uranium, although the available data do not show clear evidence of migration of the constituents into surrounding subsurface soils.

The three principal volatile organic contaminants are all dense, nonaqueous-phase liquids (DNAPLs) and therefore have the potential to collect in pools or in fractures in the bedrock at the bottom of the upper HSU. If such pools of DNAPLs exist, there is a potential for them to remain as source areas even after the removal of other sources.

2 4 2 Release Mechanisms

Radionuclides in surface soils may be released via fugitive dust and wind erosion to the air (Figure 2-16). Once in the air, the contaminated dust will either settle on plants, soils, or water. There is considerable evidence supporting this release mechanism as plutonium/americium-contaminated soil exists downwind on and in the vicinity of the Rocky Flats Plant. There is also potential for these contaminants to enter other media via surface runoff, infiltration/percolation, and biotic uptake.

Contaminants in buried waste can directly enter either the air via volatilization, or the ground water via infiltration/percolation. Ground-water quality data indicate extensive contamination in the upper HSU including the alluvium, claystone, siltstone, and Sandstone No. 1. Contamination can also enter surface water through seepage.

There is also potential for contaminants in the upper HSU to impact the lower HSU. Contaminated alluvial ground water may potentially enter lower sandstones, where they subcrop beneath the colluvium on the valley side slopes. Another potential mechanism of release into the lower HSU is by leakage through the weathered and unweathered claystone bedrock downward to a lower sandstone layer. This release mechanism is judged to have a low probability at this time as a result of the low hydraulic conductivity values reported in the unweathered claystone units. However, there is a potential for DNAPLs to infiltrate down through fractures in the bedrock. This would be most likely to occur in depressions or low areas in the bottom surface of the upper HSU. Although well logs for most pre-1986 wells do not exist, ground-water chemical data and the depth of

the wells suggest wells may be screened across more than one sandstone unit, thus representing another potential mechanism for contaminant release into the lower HSU

2 4 3 Potential Exposure Pathways

Exposure to radionuclides in surface soils can occur through multiple pathways (Figure 2-16) This figure shows all potential pathways, however, the actual pathways of significance will be determined during the risk assessment Of primary importance is exposure through direct inhalation of contaminated dust or by ingestion of contaminated soils An important secondary exposure route is through ingestion of surface water contaminated via runoff

Exposure to contaminants in surface water can occur through direct ingestion or dermal contact, or by consumption of vegetation or biota where biotic uptake has occurred

The primary potential pathways for migration of contaminants through ground-water flow to potential receptors would be either by seepage to the ground surface or by pumping from water supply wells that tap the affected ground water downgradient of the site It should be noted that there are currently no known water supply wells which tap affected ground water Other exposure pathways may include contamination of surface water by the interaction of surface water and ground water

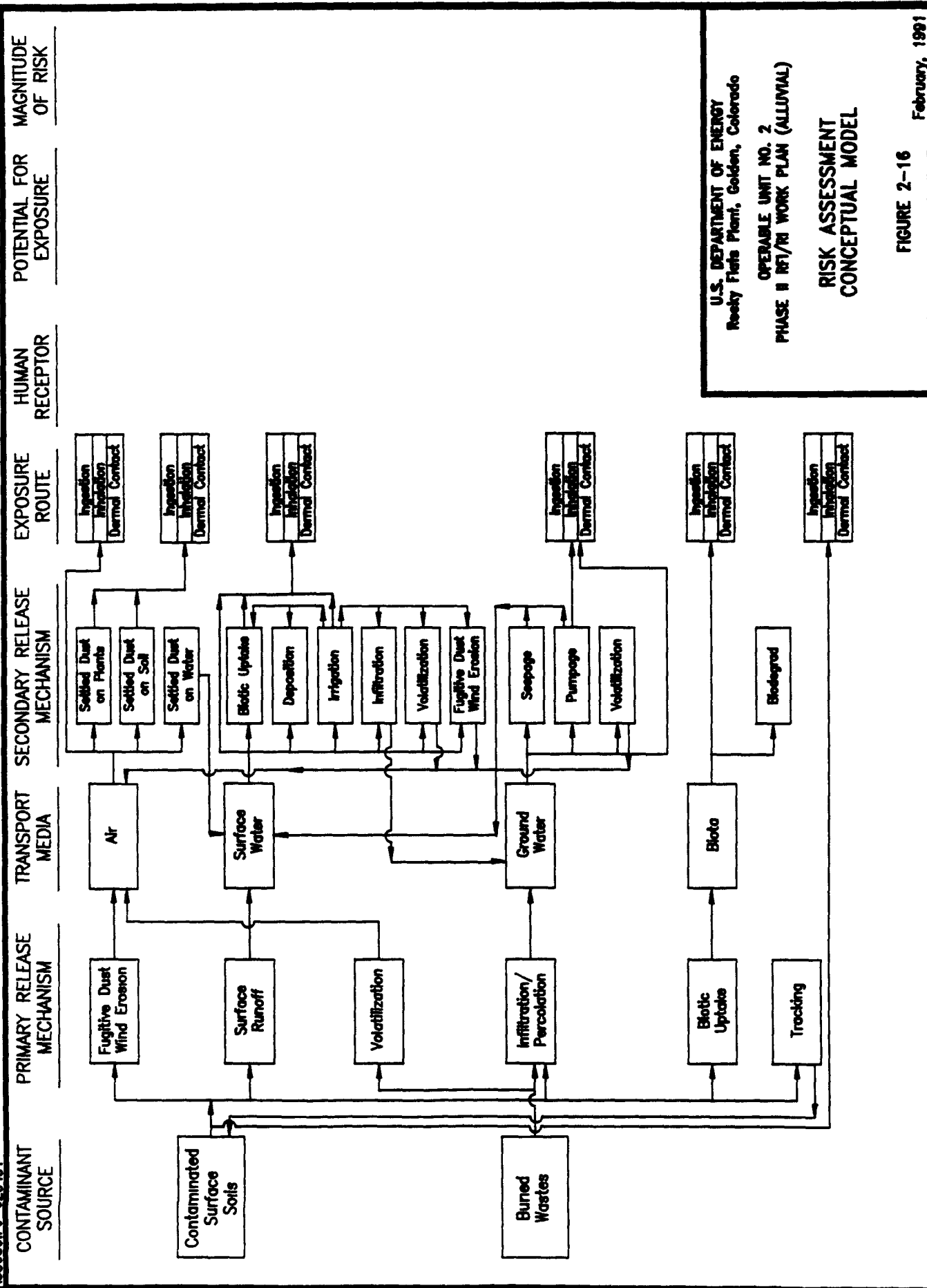
2 4 4 Receptors

Figure 2-16 summarizes the exposure routes and potential receptor populations via the potential exposure pathways described above For each pathway, there are three potential exposure routes ingestion, inhalation, and dermal contact Whether the human receptor is a resident or visitor will be determined during the risk assessment Biota may also be present at or downgradient of seep locations The potential for exposure and magnitude of risk (Figure 2-16) will be assessed during the risk assessment

2 4 5 Summary

The elements of the site conceptual model described above are shown in Figures 2-15 and 2-16 These figures depict the potential sources of contamination, mechanisms of contaminant release, exposure pathways, and primary receptors The model as pictured is based on an initial evaluation of available data As additional information is obtained, the overall model and specific portions of the model (for example, the lower hydrostratigraphic ground-water flow regime) may be refined or expanded to address the issues of concern

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Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

RISK ASSESSMENT CONCEPTUAL MODEL

FIGURE 2-16

February, 1991

2.5 SAMPLING AND ANALYSIS REQUIREMENTS FOR REMEDIAL ALTERNATIVES EVALUATION

The purpose of this section is to preliminarily identify potential remedial technologies which are consistent with the available information regarding contamination at OU No. 2. Based on the available site information, the contaminated media or areas for which remedial alternatives will be developed include wastes, soil/sediment, ground water, and surface water. The following preliminary general remedial response actions have been identified for further review and evaluation at this time:

- Complete or partial removal and treatment of wastes and contaminated soils
- In situ contaminated soils treatment
- Ground-water collection
- Infiltration and ground-water containment controls
- In situ ground-water treatment/immobilization
- Ground-water/surface water treatment
- Treated ground-water/surface water disposal

Additional response actions may be identified, interactively, as the FS proceeds. Combinations of these general response actions may be appropriate and will be evaluated during the FS. Table 2-17 presents these general response actions along with potential component technologies.

As shown in Table 2-18, there are specific requirements that are necessary to evaluate the preliminarily identified technologies. These data will provide for a thorough comparative evaluation of the technologies with respect to implementability, effectiveness, and cost, and allow for informed decisions to be made with respect to selection of preferred technologies. The FSP (Section 5.0) reflects these information requirements.

TABLE 2-17

RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GENERAL RESPONSE ACTIONS

Complete or Partial Removal and
Treatment of Contaminated Soils

In Situ Contaminated Soils Treatment

Ground-Water Collection

Infiltration and Ground-Water
Containment Controls

In Situ Ground-Water Treatment/
Immobilization

Ground-Water/Surface Water
Treatment

TYPICAL REMEDIAL TECHNOLOGIES

- Off-Site Landfill
- On-Site Treatment*/Backfill

- Immobilization (cementation and vitrification)
- Soil Flushing
- Vapor Extraction/Steam Stripping
- Bioreclamation

- Well Array
- Subsurface Drains

- Capping
- Subsurface Barriers

- Immobilization
- Aeration
- Bioreclamation

- Biological Treatment
- UV/Peroxide or UV/Ozone
- Air Stripping
- Carbon Adsorption
- Ion Exchange
- Electrodialysis
- Coagulation/Filtration

* Thermal Treatment, Solvent Extraction, Immobilization (Cementation and Vitrification), Attrition Scrubbing
for Radionuclide Decontamination

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED*
Off Site Disposal	Evaluate whether material is acceptable for off-site disposal	- Determination of applicable RCRA waste codes (40 CFR Part 261) Determination of corresponding 40 CFR Part 268 requirements to establish necessary testing if any - Full Suite of Radionuclide Analyses
On-Site Treatment/Backfill	Cost Analysis	- Vertical and Horizontal Extent* of Contamination
Thermal Treatment	Effectiveness Cost Effectiveness	- Full Suite of Organic and Inorganic Analyses* - BTU Content - Ultimate Analysis**
Solvent Extraction	Effectiveness	- Soil Type (adsorption characteristics) - Soil Organic Matter Content (adsorption characteristics)
Non In Situ (soils) Immobilization/Cementation	Determine Viscosity of Grout Material Effectiveness	- Soil Grain Size Distribution (sieve analysis) - Depth of Contamination - Depth of Water Table - Soil Permeability - Metal Content
Non In Situ (soils) Immobilization/Vitrification	Effectiveness	- Radionuclide Distribution vs Soil Grain Size
Attrition Scrubbing	Effectiveness	- Soil Grain Size Distribution (sieve analysis)
In Situ Immobilization/Cementation (soils)	Determine Viscosity of Grout Material Effectiveness	- Depth of Contamination - Depth of Water Table - Soil Permeability - Metal Content
In Situ Immobilization/Vitrification (soils)	Effectiveness	- Radionuclide Distribution vs Soil Grain Size
Soil Flushing/Bioreclamation	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD
Vapor Extraction	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
Well Array/Subsurface Drain	Hydraulic conductivity Storage (transient flow)	- Aquifer tests - Hydrogeologic characteristics

TABLE 2-18 (Continued)

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED*
Capping/Subsurface Barriers	Suitability of On-Site Soils for Use	<ul style="list-style-type: none"> - Gradation (Sieve Analysis) - Atterberg Limits (Plasticity Tests)
	Effectiveness	<ul style="list-style-type: none"> - Location of Subcropping Sandstones - Hydraulic Conductivity of Bedrock Materials
	Construction Feasibility	<ul style="list-style-type: none"> - Grade - Depth to Bedrock - % Moisture - Compaction (Proctor) - Permeability (Triaxial Permeability) - Strength (Triaxial or Direct Shear)
Immobilization (Ground Water Contaminants)	Determine Viscosity of Grout Material	<ul style="list-style-type: none"> - Soil Grain Size Distribution (sieve analysis)
In Situ Aeration (Ground Water)	Effectiveness	<ul style="list-style-type: none"> - Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
In Situ Bioreclamation (Ground Water)	Effectiveness	<ul style="list-style-type: none"> - Aquifer Tests - Hydrogeologic Characteristics - Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD - Dissolved Oxygen - NO_3^-, PO_4^{3-}, pH, Eh - Microbial Populations (density, diversity) - Microcosms
Above-Ground Biological Treatment	Effectiveness	<ul style="list-style-type: none"> - Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD - Full Suite of Organic Analyses
UV Peroxide Oxidation	Process Control	<ul style="list-style-type: none"> - Iron and Manganese - Metals - Hardness - Volatile organics
Air Stripping	Process Control Effectiveness	<ul style="list-style-type: none"> - Hardness - Iron and Manganese - Volatile organics

* The nature and extent of contamination determined through soils and water analyses for the parameters listed in Tables 2-5 and 2-9 is critical to determining the technical feasibility and cost effectiveness of the technologies listed here

** Ultimate analysis is the determination of percent carbon, hydrogen, sulfur, nitrogen, ash, and oxygen by difference for a dried sample

PHASE II RFI/RI WORK PLAN DATA QUALITY OBJECTIVES

The primary objective of a RFI/RI is to collect the data necessary to determine the nature, distribution, and migration pathways of contaminants. The RI also supports the evaluation of remedial alternatives (EPA, 1987a).

The five general goals of a RFI/RI are:

- 1) Characterize site physical features
- 2) Define contaminant sources
- 3) Determine the nature and extent of contamination
- 4) Describe contaminant fate and transport
- 5) Provide a baseline risk assessment (EPA, 1988a)

Data quality objectives (DQOs) are qualitative and quantitative statements which specify the quality and quantity of data collection required by the RI (EPA, 1987a). Through application of the DQO process, site-specific RIFS goals are established, and data needs are identified for achieving those goals. This section of the RFI/RI Work Plan reviews conclusions from the Phase I RI as a basis for Phase II RFI/RI objective and identifies data needs to meet the outlined objectives.

3.1 SITE SPECIFIC RFI/RI DQO PROCESS

Through application of the DQOs process, site-specific RFI/RI DQOs are established, and data needs are identified for achieving identified goals. DQOs are qualitative and quantitative statements that describe the quality and quantity of data required by the RFI/RI (EPA, 1987a). These determinations are facilitated through the development of DQOs.

DQOs are developed using the following three-stage process:

- STAGE 1 - Identify decision types
 - identify and involve data users
 - evaluate available data
 - develop conceptual model
 - specify objectives/decisions

- **STAGE 2 - Identify data uses and needs**
 - identify data uses
 - identify data types
 - identify data quality needs
 - identify data quantity needs
 - evaluate sampling/analysis options
 - review Precision, Accuracy, Representativeness, Comparability, and Completeness (PARCC) parameters
- **STAGE 3 - Design data collection programs**
 - assemble data collection components
 - develop data collection documentation

The three stages are implemented for each phase of the RFI/RI. The DQO stages are undertaken in an interactive and iterative manner whereby all the elements of the DQO process are continually being reviewed and applied during the execution of the data collection activities. Throughout the RFI/RI, these stages occur in a natural progression and flow together without a formal stage delineation. It may not be possible to identify all data needs during the RFI/RI activity. Data needs will become more apparent as additional data are obtained and evaluated.

3.2 PHASE I RI CONCLUSIONS

Several investigations have been conducted in the vicinity of the 903 Pad, Mound, and East Trenches Areas to date as discussed in Sections 1.0 and 2.0. General conclusions from these investigations are as follows:

- Surficial materials in the area consist of Rocky Flats Alluvium, colluvium, and valley fill alluvium.
- Bedrock beneath surficial materials consists of Arapahoe Formation claystones and sandstones that dip slightly to the east (less than two degrees). Bedrock materials are weathered below the base of surficial materials.
- The extent of Arapahoe Formation sandstones beneath these areas was not fully characterized during the Phase I RI because of the complex depositional pattern.
- Unconfined ground-water flow within the upper HSU occurs in surficial materials, subcropping sandstones, and potentially in weathered subcropping claystones. The flow system in surficial materials is not fully saturated year round. Flow in weathered claystones has not been sufficiently documented, and flow directions in subcropping sandstones are poorly defined due to the complex stratigraphy.

- Confined ground-water flow occurs in deeper sandstones (lower HSU). The flow system is poorly defined at this time due to the complex stratigraphy and facies changes.
- Ground-water recharge occurs as infiltration of incident precipitation and flow from ditches and surface water drainages.
- Discharge from the unconfined ground-water flow system occurs as evapotranspiration, seeps, and springs at the edge of the Rocky Flats pediment, to surface water in Woman Creek and South Walnut Creek, and to bedrock sandstones. Site contaminants have been identified in many of these seeps.
- Wastes have been removed from the 903 Drum Storage Site, the Pallet Burn Site, the Oil Drum Pit No. 2 Site, and the Mound Site. Wastes remain in place in all eleven trenches within the area. Further characterization of all potential contaminant sources is warranted.
- Boreholes were drilled adjacent to IHSSs in the Phase I RI, and soil samples were collected and analyzed for Hazardous Substances List (HSL) organics and metals, radionuclides, and inorganics. Further characterization of soils beneath IHSSs is needed.
- Surficial soils in the area are contaminated with plutonium, americium, and other radionuclides due to wind dispersal of particulates during cleanup of the 903 Drum Storage Site in the late 1960s. Soil sampling results indicate that these compounds are most enriched near the surface, but further investigation of smaller soil intervals is necessary to assess radionuclides distribution.
- The upper HSU contains volatile organic compounds. The principal volatile organics present are PCE, CCL₄, and TCE. The extent of these contaminants in both the unconfined and confined ground-water flow systems has not been fully determined.
- Radionuclides were elevated in sediment and unfiltered surface water samples collected during the Phase I RI. Wind dispersal of radionuclides during cleanup of the 903 Drum Storage Site is the likely source of these contaminants, although confirmation of this hypothesis is needed. There are slight indications of radionuclides in a few ground-water wells (unvalidated).
- Several major and minor elements were elevated above background in soils, ground water, surface water, and sediments, but they do not exhibit clear lateral or vertical gradients.

3.3 SITE-SPECIFIC PHASE II RFI/RI OBJECTIVES AND DATA NEEDS

Based on the Phase I RI conclusions and the conceptual site model presented in Section 2.0, site-specific Phase II RFI/RI objectives and associated data needs have been developed (Table 3-1). Specific plans for obtaining the needed data are presented in Section 5.0 (FSP).

High quality data will be collected by following the Rocky Flats Plant ER Program Standard Operating Procedures (SOP) (EG&G, 1990i), through adherence to the Rocky Flats Plant ER Program Quality Assurance Project Plan (QAPJP) (EG&G, 1990j), the QAA (Section 9.0), and the General Radiochemistry and Routine Analytical Services Protocol (GRRASP) (EG&G, 1990k). Organic and metal analyses will be performed using CLP routine analytical services (RAS), and other analyses (radionuclides and inorganics) will be performed in accordance with the GRRASP-specified methods. In addition, analytical methods with detection limits below

TABLE 3-1

PHASE II RFI/RI OBJECTIVES AND ACTIVITIES

<u>Objective</u>	<u>Field/Analytical Activity</u>	<u>Analytical Level*</u>	<u>Data Use</u>
<u>Characterize Site Physical Features</u>			
1) Determine the extent of saturation and ground-water flow directions for the unconfined flow system both spatially and temporally	Additional monitoring well and piezometer data in unexplored areas Water level data from various units from all existing and new monitor wells	NA	Site Characterization Alternatives Evaluation
2) Describe the interaction between the surface water and ground-water pathways	Ground-water flow directions, quality, and potentiometric surface Seep locations, flow, and water quality	II(field) IV(off-site analytical)	Site Characterization Alternatives Evaluation
3) Determine the hydraulic connection between surficial deposits and bedrock and quantify material properties	Long term pumping test data to evaluate hydraulic conductivity and storage Tracer test data to evaluate effective porosity	NA	Site Characterization Alternatives Evaluation
4) Delineate the Arapahoe Formation sandstones	Additional drilling and seismic profile data	NA	Site Characterization Alternatives Evaluation
<u>Characterize Contaminant Sources</u>			
1) Characterize the nature and distribution of waste materials remaining on-site	Chemical analyses of wastes and soils beneath the wastes Analyze samples for TCL volatiles, semi-volatiles, pesticides/PCBs, and Target Analyte List (TAL) metals, as well as radionuclides and inorganics	IV	Site Characterization Alternatives Evaluation Risk Assessment

TABLE 3-1 (Continued)
PHASE II RFI/RI OBJECTIVES AND DATA NEEDS

<u>Objective</u>	<u>Field/Analytical Activity</u>	<u>Analytical Level</u>	<u>Data Use</u>
<u>Characterize Contaminant Sources (Continued)</u>			
2) Characterize soils beneath wastes as well as soils at sites where wastes have been removed as potential contaminant sources	Same as above	IV	Site Characterization Alternatives Evaluation Risk Assessment
3) Identify which sites are sources of ground water and surface water contamination	Ground-water levels and quality beneath sites. IHSS specific upgradient and downgradient water quality data Additional surface water quality data from existing seep stations	IV	Site Characterization Alternatives Evaluation Risk Assessment
<u>Characterize the Nature and Extent of Contamination</u>			
1) Determine the horizontal and vertical extent of surficial radionuclide soil contamination due to wind dispersion	Radionuclide data on surficial soil scrapes. Sampling will follow Colorado Department of Health procedures to define the horizontal extent of radionuclide contamination, these samples will be collected within the RFI/RI study area as well as in the plant buffer zone Radionuclide data on soil samples from test pits dug in the same areas as surficial soil sample collection to define the vertical extent of radionuclide migration into the soil profile	IV	Site Characterization Alternatives Evaluation Risk Assessment

TABLE 3-1 (Continued)

PHASE II RFI/RI OBJECTIVES AND DATA NEEDS

Objective	Field/Analytical Activity	Analytical Level	Data Use
<u>Characterize the Nature and Extent of Contamination (Continued)</u>			
2) Determine the nature and extent of ground-water contamination	Ground-water chemistry data for surficial materials and subcropping Arapahoe sandstones between areas with and without known ground-water contamination to delineate the extent of contamination. Samples will be analyzed for TCL volatiles, semi-volatiles and pesticides/PCBs, TAL metals, radionuclides, and inorganics	IV	Site Characterization Alternatives Evaluation Risk Assessment
3) Characterize surface water and seep quality	Quarterly collection of surface water seep samples from existing monitoring stations. Samples will be analyzed for TCL volatiles, TAL metals, radionuclides, and inorganics. Analyze surface water samples for both dissolved and total metals and radionuclides to determine if constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations	IV	Site Characterization Alternatives Evaluation Risk Assessment
<u>Provide Data for Baseline Risk Assessment</u>			
1) Describe contaminant fate and transport	Data on the physicochemical processes associated with site contaminants based on existing literature and site specific information	NA	Risk Assessment

TABLE 3-1 (Continued)

PHASE II RFI/RI OBJECTIVES AND ACTIVITIES

<u>Objective</u>	<u>Field/Analytical Activity</u>	<u>Analytical Level</u>	<u>Data Use</u>
<u>Provide Data for Baseline Risk Assessment (Continued)</u>			
2) Assess potential interim and final remedial alternatives	Information on the effectiveness of interim and final remedial alternatives	NA	Risk Assessment
3) Assess the threat to public health and the environment from the no action remedial alternative	Reference doses and slope factors for contaminants at the site	NA	Risk Assessment
<u>Provide Data for Feasibility Study</u>			
1) Assess potential interim and final remedial alternatives	Information on the effectiveness, implementability, and cost of interim and final remedial alternatives. This includes site geological and hydrogeochemical data, literature data on remedial alternatives performance; treatability study data; and design, construction, and operation and maintenance costs for remedial alternatives	IV (treatability studies)	Alternatives Evaluation
<u>Provide Data for Environmental Evaluation</u>			
1) Assess the bio-availability and toxicity of the contaminants to the flora and fauna	Field assessments, toxicity testing, and biomarkers to determine ecological effects	IV	Site Characterization Alternatives Evaluation Risk Assessment

* See Table 3-2 for explanation
 ** Radionuclides are considered non-conventional parameter and therefore the analytical level for these constituents is "N/A"
 NA Not applicable

or near chemical-specific ARARS are presented in Section 7.0 (Table 7-1) and will be used to facilitate comparison of resulting data to ARARs. Table 3-2 explains the required analytical levels referenced in Table 3-1.

TABLE 3-2
LEVEL OF ANALYSIS

Required Analytical Level	Task
Level I (Field Screens)	<ul style="list-style-type: none"> • Water level measurement • pH measurement • Eh measurement • Screening for organics (OVA/HNu) • Screening for radionuclides (beta-gamma) • Temperature • Specific conductance • Geophysical surveys
Level II (Field Analyses)	<ul style="list-style-type: none"> • Screening for organics (GC) • Screening for radionuclides (gross beta/gross alpha, gamma spec) • Analysis of engineering properties
Level III (Laboratory Analyses using EPA Standard Methods)	<ul style="list-style-type: none"> • Major ion analysis • Organics analysis • Inorganics analysis
Level IV (Laboratory Analyses using EPA CLP Methods)	<ul style="list-style-type: none"> • Analysis of Target Compound List (TCL) and Target Analyte List (TAL)
Level V (Nonstandard Analyses)	<ul style="list-style-type: none"> • Radiological analyses • Chemical analyses requiring modification of standard methods • Special Analytical Services (SAS)

Source EPA, (1987a)

REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

4 1 REMEDIAL INVESTIGATION TASKS**4 1 1 Task 1 - Project Planning**

The project planning task includes all efforts required to initiate this Phase II RFI/RI of OU No 2. Activities undertaken for this project have included a detailed review of the Phase I RI results as well as other previous investigation results, a review of historical aerial photography, a preliminary evaluation of ARARs, and scoping of the Phase II RFI/RI. Results of these activities are presented in Sections 1 0 (Introduction) and 2 0 (Phase I RI Site Evaluation).

During the Phase I RI, a complex depositional pattern was recognized in the bedrock beneath the 903 Pad, Mound, and East Trenches Areas. A high resolution seismic reflection program is currently being implemented to further define the location, extent, and orientation of bedrock sandstone units beneath the area. Results of this investigation will be evaluated in scoping of the Phase II RFI/RI (bedrock) for OU No 2.

Two project planning documents, including this Work Plan, have been prepared which pertain to this Phase II RFI/RI as required by the IAG between DOE, EPA, and CDH. This Work Plan presents results of the project planning task in addition to plans for the Phase II RFI/RI. A Field Sampling Plan (FSP) is included in this document (Section 5 0) which presents the locations, media, and frequency of sampling efforts. The second document required by the IAG is a Sampling and Analysis Plan (SAP). The IAG specifies that the SAP is to include a QAPJP and SOP for all field activities. A draft QAPJP for site-wide RCRA and CERCLA activities (EG&G, 1990j) was submitted to the regulatory agencies in August 1990. A GRRASP (EG&G, 1990k) has also been prepared which is the scope of work for analytical services. The current Rocky Flats Plant SOPs were submitted to EPA and CDH in August 1990 (EG&G, 1990l). A Health and Safety Plan (HSP) defining the protocol for protection of field workers during Phase II operations will be submitted as well. The HSP will be based on the Health and Safety Program Plan currently being finalized based on comments from EPA and CDH.

4 1 2 Task 2 - Community Relations

In accordance with the draft IAG, the Rocky Flats Plant is developing a Community Relations Plan (CRP) to inform and actively involve the public in decision making regarding environmental restoration activities. The plan will address the needs and concerns of the surrounding communities as identified through approximately

80 interviews with federal, state, and local elected officials, businesses, medical professionals, educational representatives, interest groups, media, and residents adjacent to the Plant

The draft CRP was submitted to EPA and CDH for review in November 1990 in accordance with the draft IAG schedules. Accordingly, a site-specific CRP is not required for OU No. 2. Following review by EPA and CDH, the proposed plan was distributed for public review and comment in January 1991. The proposed CRP is scheduled for finalization in August 1991.

During the February 1990 public hearing on the IAG, several commentators requested the development of an Interim CRP for implementation until the final plan is available in August 1991. A draft Interim Community Relations Plan was prepared and implemented in January 1991 pending finalization of the proposed plan.

Current community relations activities concerning environmental restoration include participation by Plant representatives in informational workshops, meetings of the Rocky Flats Environmental Monitoring Council, briefings for citizens, businesses, and surrounding communities on environmental restoration and monitoring activities, and public comment meetings on various ER Program plans and actions.

In addition, a Speakers Bureau provides Plant speakers for presentations to civic groups and educational organizations, and a public tours program allows the public to visit the Rocky Flats Plant. The Plant also produces fact sheets and periodic updates on environmental restoration activities for public information and responds to numerous public inquiries concerning the Plant.

4.1.3 Task 3 - Field Investigation

The Phase II RFI/RI field investigation is designed to meet the objectives outlined in Section 3.2. The following activities will be performed as part of the field investigation:

- Drill and sample soils and wastes within IHSSs
- Sample surficial soils for radionuclides, and subsurface soils for radionuclides, TCL volatiles, semi-volatiles, pesticides/PCBs, TAL metals, inorganics and soil physical characteristics (e.g., organic matter, ambient, grain size distribution, cation exchange capacity, etc.)
- Install and sample ground-water monitoring wells to characterize the nature and extent of ground-water contamination and the hydraulic connection between surficial materials and bedrock
- Perform aquifer tests, tracer tests, and geotechnical tests
- Collect surface water and sediment samples

- Take water level measurements, stream flow measurements, and ground-water quality parameters

Sample locations, frequency, and analyses are presented in Section 5.0. All field activities will be performed in accordance with the Rocky Flats Plant ER Program SOP (EG&G, 1990l).

4.1.4 Task 4 - Sample Analysis and Data Validation

Analytical methods for chemical analyses are provided in the GRRASP (EG&G, 1990k). Also provided in this document are the analytical detection limits.

Data will be reviewed and validated by the EG&G Environmental Monitoring and Assessment Division (EMAD) laboratory validation subcontractor. Results of data review and validation activities will be documented in data validation reports and the RFI/RI report. EPA data validation functional guidelines will be used for validating organic and inorganic (metals) data (EPA, 1988b). Validation methods for radiochemistry and major ions data have not been published by the EPA, however, data and documentation requirements have been developed by the ER Department. The functional guidelines which will be used to evaluate analytical data are presented in the QAPjP (EG&G, 1990j) and GRRASP (EG&G, 1990k).

4.1.5 Task 5 - Data Evaluation

Data collected during the Phase II RFI/RI will be incorporated into the Rocky Flats Environmental Database System (RFEDS) and used to better define site characteristics, source characteristics, the nature and extent of contamination, and contaminant migration rates. The RFEDS is used to track, store, and retrieve project data. Data will be input to the RFEDS via diskettes subsequent to data validation as outlined in the ER Program QAPjP (EG&G, 1990j). Hard copy reports will then be generated from the system for data interpretation and evaluation.

4.1.5.1 Site Characterization

Geologic and hydrologic data will be incorporated into existing site maps and cross-sections. Geologic data will be used to detail the stratigraphy of surficial materials and weathered bedrock within source areas and to map the extent of paleochannels in the top of bedrock. Hydrologic data will be used to evaluate seasonal variations in water levels, ground-water flow, and the extent of saturated surficial materials. Also evaluated will be hydraulic conductivity, storativity, ground-water velocity, contaminant migration rates, and the interaction between ground water and surface water.

4 1.5 2 Source Characterization

Analytical data from source boreholes will be used to

- Verify IHSS locations
- Characterize the nature of source contaminants
- Characterize the lateral and vertical extent of source contaminants
- Determine the maximum on-site contaminant concentrations
- Quantify the volume of source materials

At those IHSS locations which are trenches, geologic data from the source boreholes will also determine the trench depths and characterize any trench contents

4 1 5 3 Nature and Extent of Contamination

Analytical data from soil, sediment, ground-water, surface water, and routine air sampling efforts will be used to characterize the nature and extent of contamination. The criteria for the identification of contamination will be analyte-specific. For organic compounds, any detectable concentrations in samples that are not attributable to laboratory contamination [defined according to CLP Protocol (EPA, 1988b)] will be considered likely evidence of contamination. Unvalidated data or invalid data will be considered qualitative estimates of contamination only. For inorganic compounds (including radionuclides), only those concentrations which exceed expected concentrations in background shall constitute evidence of contamination. The statistical techniques which shall be used to compare concentrations of inorganic compounds collected as part of the Phase II RFI/RI to background concentrations are documented in the Background Geochemical Characterization Report (Rockwell International, 1989h). Essential to the implementation of these statistical techniques for ground-water and borehole samples is the classification of each analytical datum according to an appropriate geologic unit (such as Rocky Flats Alluvium or colluvium). This identification of the appropriate geologic unit will be based on geological data collected during the Phase II RFI/RI. Background for inorganic analytes will be further characterized and evaluated in the context of the potential role of evaporative concentration as a mechanism for localized occurrences of inorganic constituents at high concentrations.

The extent of contamination will be delineated through the use of contaminant isopleths maps and possibly cross sections. The possibility of using kriging to contour the isopleths of the most widely distributed contaminants will be investigated with explicit attention to the assumptions required by kriging (Davis, 1986), and kriged contours will be generated only if appropriate. Investigations to date indicate difficulty in identifying the source of contamination because of the close proximity of several possible sources. The statistical

technique of principal component analysis will be investigated as a method of identifying the effects of multiple sources. The ability to estimate the individual effects of multiple sources at intermediate sampling sites will aid in the mapping of plumes and in the understanding of the transport of contaminants by the ground-water flow system.

Comparisons of analytical data between ground water and surface water will be made to investigate the movement of contaminants from one pathway to another. Temporal variations of contaminant concentrations in ground water and surface water will be evaluated both for seasonality and long-term trends to determine contaminant migration rates.

Analytical data from surficial soil scrapes and vertical soil profiles will be evaluated in order to characterize the areal and vertical distribution of plutonium and americium contamination in remedial investigation areas and in other Plant areas (buffer zone) to the south and east.

4.1.5.4 Evaluation of Proposed Remedial Alternatives

The evaluation of proposed remedial alternatives will be based primarily on the information derived for the purpose of site and source characterization. Geotechnical data from source boreholes will be used to evaluate the effectiveness of technologies pertinent to soil remediation, e.g.

- Attrition scrubbing
- Solvent extraction
- Vapor extraction/steam stripping
- Soil immobilization
- Soil flushing/bioreclamation
- In situ vitrification
- Capping/subsurface barriers

4.1.6 Task 6 - Baseline Risk Assessment

A baseline risk assessment will be prepared for the 903 Pad, Mound, and East Trenches Areas as part of the Phase II RFI/RI to evaluate the potential threat to the public health and the environment in the absence of remedial action. The baseline risk assessment will provide the basis for determining whether or not remedial action is necessary in the area and will serve as the justification for performing remedial action (EPA, 1988a). The risk assessment will assume no institutional controls.

Several objectives will be accomplished under the risk assessment task including identification and characterization of the following (EPA, 1988a)

- Toxicity and levels of hazardous substances present in relevant media (e g , air, ground water, soil, surface water, sediment, and biota)
- Environmental fate and transport mechanisms within specific environmental media and cross-media fate and transport where appropriate
- Potential human and environmental receptors
- Potential exposure routes and extent of actual or expected exposure
- Extent of expected impact or threat, and the likelihood of such impact or threat occurring (e g , risk characterization)
- Level(s) of uncertainty associated with the above

The public health risk assessment and the environmental evaluation will be performed in accordance with EPA and other guidance documents listed in Table 4-1 The risk assessment will address the potential public health and environmental impacts associated with the site under the no-action alternative (no remedial action taken) This assessment will aid in the selection of site remedies based on the contaminants of concern and the environmental media associated with potential risks to public health and the environment

4 1 6 1 Public Health Evaluation

The risk assessment process is divided into five tasks (EPA, 1988a), including

- Data collection/contaminant identification
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Analysis of uncertainties

The task objectives and description of work for each task are described below

Data Collection/Contaminant Identification

The objective of contaminant identification is to screen the information that is available on hazardous substances or wastes present at the site and to identify contaminants for the risk assessment process

TABLE 4-1

**EPA GUIDANCE DOCUMENTS WHICH WILL BE USED
IN THE RISK ASSESSMENT TASK**

- CERCLA Compliance With Other Laws Manual -- Office of Emergency and Remedial Response The guidance is intended to assist in the selection of on-site remedial actions that meet the applicable or relevant and appropriate requirements (ARARs) of the Resource Conservation and Recovery Act (RCRA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Clean Air Act (CAA) and other federal and state environmental laws as required by CERCLA, Section 121 (EPA, 1988d)
- Ecological Assessment of Hazardous Waste Sites A Field and Laboratory Reference -- Office of Solid Waste and Emergency Response EPA 600-3/89/013 This report is a field and laboratory reference document that provides guidance on designing, implementing, and interpreting ecological assessments of hazardous waste sites It includes sections on ecological endpoints, field sampling design, quality assurance, aquatic and terrestrial toxicity and field survey methods, recommended biomarkers, and data analysis (EPA, 1989c)
- EPA's Integrated Risk Information System (IRIS) -- Office of Research and Development (continuously updated) Agency's primary source of chemical-specific toxicity and risk assessment information Includes narrative discussion of toxicity database quality and explains derivation of Reference Doses, cancer potency factors, other key dose response parameters IRIS presents information that updates data originally presented in Exhibits A-4 and A-6 of the SPHEM (see below) Further information IRIS Users Support, 513-569-7254 (EPA, 1987b)
- Exposure Factors Handbook -- Office of Research and Development (March 1989), EPA/600/8-89/043 Provides statistical data on the various factors used in assessing exposure, recommends specific default values to be used when site-specific data are not available for certain exposure scenarios Further information Exposure Methods Branch, 202-382-5988 (EPA, 1989e)
- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA -- Office of Emergency and Remedial Response EAA/540/G-89/004 This guidance document is a revision of the U S EPA's 1985 guidance It describes general procedures for conducting an RI/FS (EPA, 1988a)
- Health Effects Assessment Summary Tables (HEAST) -- Office of Research and Development/Office of Emergency and Remedial Response (updated quarterly) Since the IRIS chemical universe (while growing), is currently incomplete, the HEAST has been produced to serve as a "pointer" system to identify current literature and toxicity information on important non-IRIS chemicals While HEAST data in some cases may be "Agency-verified", the information is considered valuable for Superfund risk assessment purposes Available from Superfund docket, 202-382-3046 (EPA, updated quarterly)
- OSWER Directive on Soil Ingestion Rates -- Office of Solid Waste and Emergency Response (January 1989), OSWER Directive #9850 4 Recommends soil ingestion rates for use in risk assessment when site-specific information is not available Available from Darlene Williams, 202-475-9810 (EPA, 1989b)
- Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual, Interim Final (RAGS-EEM) -- Office of Emergency and Remedial Response (March 1989), EPA/540/1-89/001A Provides program guidance to help remedial project managers and on-scene coordinators manage ecological assessment at Superfund sites (EPA, 1989d)

Sheet 1 of 2

TABLE 4-1 (Continued)

**EPA GUIDANCE DOCUMENTS WHICH WILL BE USED
IN THE RISK ASSESSMENT TASK**

- Risk Assessment Guidance for Superfund. Human Health Evaluation Manual Part A. Interim Final -- Office of Emergency and Remedial Response This volume provides updated risk assessment procedures and policies, specific equations and variable values for estimating exposure, and a hierarchy of toxicity data sources There is an expanded chapter on risk characterization to help summarize information for the decision makers and detailed descriptions of uncertainties in risk assessment (EPA, 1989a)
 - Superfund Exposure Assessment Manual (SEAM) -- Office of Emergency and Remedial Response (April 1988), EPA/540/1-88/001 Provides a framework for the assessment of exposure to contaminants at or migrating from hazardous waste sites Discusses modeling and monitoring* (EPA, 1988c)
 - Superfund Public Health Evaluation Manual (SPHEM) -- Office of Emergency and Remedial Response The current program risk assessment guidance manual Explains how to set preliminary remediation goals, and evaluate risks of remedial alternatives
 - Superfund Risk Assessment Information Directory (RAID) -- Office of Emergency and Remedial Response (November 1986), EPA/540/1-86/061 Describes sources of information useful in conducting risk assessments Currently under revision *
- * Available from Center for Environmental Research Information, 513-569-7562

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Previous work characterizing aspects of the Rocky Flats Plant and the surrounding area has been done. Additional sampling and analysis of various media will take place in order to support the human health risk assessment, the ecological assessment, and to further characterize the site. For this risk assessment, all chemicals detected above background concentrations in site-associated media at OU No. 2 will be treated as site contaminants for the purpose of public health evaluation. These include:

- Chemicals positively identified in one or more samples in a given medium
- Chemicals which have been tentatively identified and have historically been associated with the site or confirmed by special analysis

The potential transformation products of site-associated chemicals will be considered to the extent possible by the availability of chemical-specific transformation data and information regarding site-specific environmental conditions (e.g., potential for biodegradation).

All chemicals present below background will be eliminated from further consideration. In addition, after the completion of the exposure assessment, any site contaminants which appear to have no potential for exposure will not be evaluated. All chemicals that are deleted and the rationale for their deletion will be discussed.

Exposure Assessment

The objectives of the exposure assessment are to identify actual or potential exposure pathways, to characterize potentially exposed populations, and to determine the extent of exposure. A conceptual model for exposure assessment is shown in Figure 2-16. An exposure pathway is comprised of four elements:

- A source and mechanism of chemical release to the environment
- An environmental transport medium (e.g., air, ground water) for the released constituent
- A point of potential contact of humans or biota with the affected medium (the exposure point)
- An exposure route (e.g., inhalation of contaminated dust) at the exposure point

The exposure assessment process will include the following actions:

- Analyze the probable fate and transport of compounds for both the present and the future uses
- Identify the human populations in the area, typical activities that would influence exposure, and sensitive population subgroups
- Identify potential exposure pathways under current and future land use conditions

- Develop exposure scenarios for each identified pathway and select those scenarios that are plausible
- Identify scenarios assuming both existing and potential future uses
- Identify the exposure parameters to be used in assessing the risk for all scenarios
- Develop an estimate of the expected exposure levels from the potential release of contaminants

Appropriate exposure scenarios will be identified for the site. Scenarios which could potentially be considered include residential, commercial/industrial, and/or recreational. Factors to be examined in the pathway and receptor identification process will include

- Location of contaminant source
- Local topography
- Local meteorological data
- Local geohydrology/surface water hydrology
- Surrounding land use
- Local water use
- Prediction of contaminant migration
- Persistence and mobility of migrating contaminants

For each migration pathway and for current and future conditions, receptors will be identified and characterized. Potential receptors will be defined by the appropriate exposure scenarios.

To assess the potential adverse health effects associated with access to the site, the potential level of human exposure to the selected chemicals must be determined. Intakes of exposed populations will be calculated separately for all appropriate pathways of exposure to chemicals. Then for each population-at-risk, the total chronic intake by each route of exposure will be calculated by adding the intakes from each pathway. Total oral, inhalation, and dermal chronic exposures will be estimated separately. Chronic daily intakes will be calculated based on the upper 95 percent confidence limit of the exposure data.

In general, chemical intakes will be estimated using available, region-specific exposure parameters developed by the EPA. Any deviation from these parameters will be documented and submitted to the regional EPA office for approval prior to preparation of the risk assessment.

Toxicity Assessment

In accordance with EPA's risk assessment guidelines, the projected concentrations of chemicals of concern at exposure points will be compared with ARARs to judge the degree and extent of risk to public health and the environment (including plants, animals, and ecosystems). Because many ARARs do not exist for certain media (such as soils) nor are all ARARs necessarily health based, this comparison is not sufficient in itself to satisfy the requirements of the risk assessment process. Moreover, receptors may be exposed to contaminants from more than one medium so that their total doses might exceed risk reference doses (RfDs) and/or might result in an excess cancer risk greater than an acceptable target risk, as defined by EPA (e.g., 10^{-6} to 10^{-4}). Nevertheless, the comparison with standards and criteria is useful in defining the exceedance of institutional requirements. Aside from the ARARs discussed in Section 7.0, the following criteria will be examined:

- Drinking water health advisories
- Ambient water quality criteria for protection of human health
- Center for Disease Control and Agency for Toxic Substances and Disease Registry soil advisories
- National Ambient Air Quality Standards

Critical toxicity values (e.g., numerical values derived from dose-response information for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity reference values from EPA's Integrated Risk Information System (IRIS) will be used in preference to other EPA reference values.

A summary of any toxicological studies performed will be provided for all chemicals above background in the baseline risk assessment. The quality of these studies and their usefulness in estimating human health risks will be described. A more detailed explanation of the toxic effects of target chemicals will be provided in the appendices to the human health risk assessment and the environmental evaluation. Toxicity reference values will also be summarized. For the human health risk assessment, this will include a brief description of the studies upon which selected reference values were based, the uncertainty factors used to calculate RfDs, and the EPA weight-of-evidence classification for carcinogens. For those chemicals without EPA toxicity reference values, a literature search, including computer data bases, will be conducted for selected compounds. A toxicity value will then, if possible, be derived from this information. EPA will be consulted regarding the appropriateness of the data and the methodologies to be used in deriving reference values. Uncertainties regarding the toxicity assessment will be discussed.

Two types of critical toxicity values will be used

- The risk reference dose (RfD)
- Slope factor (for carcinogenic chemicals only)

Risk Characterization

Risk characterization involves integrating exposure assumptions and toxicity information to quantitatively estimate the risk of adverse health effects. Risk characterization will be performed in accordance with EPA guidance.

Non-carcinogenic risk will be evaluated by comparison of contaminant intakes at exposure points to chronic reference doses for protection of human health. Carcinogenic risk will be quantified using carcinogenic potency factors. Risk will be qualitatively evaluated for those contaminants for which evaluation is not possible.

The results of the baseline risk assessment will be used to define and evaluate the remedial alternatives during the FS.

Uncertainty Analysis

An uncertainty analysis will be performed to identify and evaluate non-site and site-specific factors that may produce uncertainty in the risk assessment, such as assumptions inherent in the development of toxicological endpoints (potency factors, reference doses) and assumptions considered in the exposure assessment (model input variability, population dynamics). First order or statistical sampling (Monte-Carlo) techniques may be employed. The goal of this task will be to quantify, to the extent practicable, the magnitude and extent of uncertainty propagated through the risk assessment process. The uncertainty analysis will present the spectrum of potential risks under specified scenarios so the risk management decision maker can obtain an understanding of the level of confidence associated with all estimates of potential human health risk.

4.1.6.2 Environmental Evaluation

The EEWP for OU No. 2 is presented in Section 6.0. The principal focus of the EEWP is on an environmental evaluation methodology which is described in Section 6.2. The basic methodological components are addressed in detail. The overall purpose of the OU No. 2 EE is to document a qualitative and, where possible, a quantitative assessment of actual or potential threats of damage to the environment including wildlife and vegetation species, habitats, and sensitive ecosystems. The EE's multiple objectives are listed in Section 6.1.3.

The EEWP is based on

- The EPA's mandate under the CERCLA, or Superfund, to protect human health and the environment from actual or threatened releases of hazardous substances
- The requirement of the National Contingency Plan (NCP) [300.430(e)(2)(G)] to perform EEs at CERCLA sites in order to assess threats to the environment
- The EPA Risk Assessment Guidance for Superfund Volume II Environmental Evaluation Manual (EPA, 1989a)
- The FFCAO entered into between the DOE, EPA Region VIII, and the State of Colorado, also known as the IAG, which requires the DOE to perform environmental response activities at the Rocky Flats Plant that are consistent with the requirements of CERCLA and other applicable federal and state laws and regulations

The EEWP provides a generalized overview of the Rocky Flats Plant, establishes EE purposes and objectives, details an EE methodology, and identifies specific tasks to be undertaken as part of the EE implementation process in order to assess actual or potential ecological consequences of releases of contaminants from the 903 Pad, Mound, and East Trenches Areas assuming no remedial action. Attachment 2.0 of this Work Plan contains an FSP which describes a comprehensive program for sampling and analysis of biological resources and ecosystems within and near OU No. 2.

The EEWP describes the process by which actual and potential environmental risks deriving from existing OU No. 2 conditions will be assessed, relying in part on data collected during the Phase I RI and Phase II RFI/RI. When the EEWP is implemented, it will characterize the levels of toxicity of hazardous substances present in the environment, the fate and transport of contaminants, and the actual and potential exposure of contaminants to plants and animals. The EE approach has much in common with the human health risk assessment in that the same basic steps are employed: data collection and evaluation, contaminant identification, exposure assessment, toxicity assessment, and risk characterization. The process is illustrated in Figure 6-1 of the EEWP in Section 6.0. The major guidance document that will be relied upon in implementing the EEWP is the EPA Environmental Evaluation Manual (EPA, 1989d).

Although the principal focus of the EEWP is on the environmental evaluation methodology detailed in Section 6.2, and the FSP in Attachment 2.0, six specific tasks under which the EE will be organized and performed are identified in Section 6.3. These tasks are as follows:

Task 1 -- Review of Existing Information

Task 2 -- Data Evaluation and Analysis

Task 3 -- Field Investigations (including Field Sampling)

Task 4 -- Ecological Risk Assessment

Task 5 -- Environmental Evaluation Report

Task 6 -- Project Management and Documentation

EE program flexibility will be required as the nature and scope of any particular task may need to be modified depending on changes in the existing database, the results of qualitative field surveys, and the data derived from the quantitative field sampling and analysis

The EEWP FSP (Attachment 2 0) will be integrated with the OU No 2 Phase II RFI/RI field sampling program given in Section 5 0, as well as sampling by the Rocky Flats EMAD. The sampling procedures discussed have been designed to follow protocols already in place at the Rocky Flats Plant and those recommended by EPA and U S Fish and Wildlife Service. Overall objectives of the FSP are to (1) characterize biological resources in order to conduct the ecological impact assessment, and (2) acquire data needed to measure the effects of contaminants on ecological systems. Detailed sampling program objectives are listed in Section 2 2 of Attachment 2 0.

The FSP will consist of both qualitative field surveys and quantitative field sampling. Both programs will identify, characterize and assess aquatic ecosystems (periphyton, benthic macroinvertebrates, and fish) and terrestrial organisms (grassland vegetation, small mammals, invertebrates, and wetlands). The FSP also addresses quality assurance/quality control, sample documentation, equipment calibration and maintenance, health and safety, waste management, sample handling and analytical protocols, and statistical analysis and procedures.

4 1 7 Task 7 - Treatability Studies/Pilot Testing

A draft Treatability Studies Plan (TSP) (EG&G, 1990I) was prepared and submitted to the regulatory agencies in September 1990 in accordance with the draft IAG schedule. This document provides comprehensive plans for treatability studies designed for remediation of waste sources, soils, and water at all operable units at Rocky Flats Plant. The Treatability Studies Program that is addressed by the TSP will serve to determine the operability, reliability, cost-effectiveness, and overall implementability of technologies that are appropriate for the types of contaminants and contaminated media at the Plant but are not adequately proven.

The Treatability Studies Program will address practical (e.g., conventional) technologies and innovative/emerging technologies. The TSP identifies both practical and innovative technologies that are

applicable to the Rocky Flats Plant contamination, screens these technologies to determine candidates for treatability studies, and provides statements of work for each candidate treatability study. Subsequently, work plans will be prepared for conduct of the treatability studies. The treatability studies will then be performed, and a Treatability Studies report (draft report due in May 1993) will be prepared. The report timing will allow utilization of this information for the OU No. 2 CMS/FS report (draft report due November 1993). However, the draft IAG schedules for OU No. 2 also call for scoping of treatability studies specific to OU No. 2 beginning in October 1992, with studies completed by June 1993. During the scoping of treatability studies, the need to acquire additional data on the technologies relevant to OU No. 2 will be determined. Work plans will subsequently be prepared as appropriate. Results of treatability studies performed pursuant to the surface water IM/IRA will be evaluated in determining the need to acquire additional data.

The Treatability Studies Program and the OU No. 2 treatability studies (for IM/IRA and CMS/FS) will be a coordinated effort with common project control. The staff assigned for project control will also supervise site-specific treatability studies for other OUs as well as the Rocky Flats Plant contributions to the DOE Office of Technology Development (OTD) integrated demonstrations and the EPA Superfund Innovative Technology Evaluation (SITE) program. For example, the treatability studies project staff are participating in OTDs integrated demonstrations of plutonium in soils that is being conducted at the Nevada Test Site. Participation in the numerous treatability study programs will allow evaluation of all applicable innovative technologies, and will "streamline" each program to avoid duplication of effort.

4.1.8 Task 8 - Remedial Investigation Report

A draft Phase II RFI/RI Report will be prepared to consolidate and summarize the data obtained during Phase I and II RI field work. This report will

- Describe in detail the field activities which serve as a basis for the RI report. This will include any deviations from the work plan which occurred during implementation of the field investigation.
- Thoroughly discuss site physical conditions. This discussion will include surface features, meteorology, surface water hydrology, surficial geology, ground-water hydrology, demography and land use, and ecology.
- Present site characterization results from all RI investigative activities at OU No. 2 in order to further characterize the nature and extent of contamination as well as the rate of contaminant migration. The media to be addressed will include contaminant sources, soils, ground water, surface water, air, and biota. All relevant quarterly ground-water and surface water sampling results will be used in this assessment.
- Discuss contaminant fate and transport. This discussion will include potential migration routes, contaminant persistence, and contaminant migration.

- Present a baseline risk assessment The risk assessment will include human health and environmental evaluations
- Present a summary and conclusions

4.2 FEASIBILITY STUDY TASKS

A CMS/FS is planned for the 903 Pad, Mound, and East Trenches Areas to develop and evaluate remedial alternatives for clean up of contaminated soils, ground water, and surface water Results of the Phase II RFI/RI, including the ARARs analysis and baseline risk assessment will allow development of remediation goals to guide this process

The CMS/FS process occurs in two phases The first phase consists of developing and screening remedial alternatives, and the second phase includes a detailed analysis of alternatives (EPA, 1988a) Each of these two phases is discussed in the following sections

4 2 1 Task 9 - Remedial Alternatives Development and Screening

The goal of this task is to identify and screen remedial alternatives The work consists of five parts

- Developing media-specific preliminary remediation goals
- Identifying and screening remedial technology groups
- Identifying and screening remedial technology options within each technology group
- Developing remedial alternatives
- Screening remedial alternatives

4 2 1 1 Establish Preliminary Remediation Goals

Preliminary remediation goals will be established early in the FS to support the development and screening of remedial alternatives Preliminary remediation goals will be applied as performance objectives for evaluating those specific technology processes identified as candidate components of viable remedial action alternatives Within this context, preliminary remediation goals will be used to perform the following

- 1 Identify media, areas of the OU, and chemicals requiring remediation This will be accomplished by comparing, for each affected media, measured or estimated concentrations to preliminary remediation goals

- 2 Identify the degree of remedial action required for each media. This will be accomplished by comparing, for each affected media, measured or estimated concentrations in areas indicating potential remediation with preliminary remediation goals.
- 3 Combining 1 and 2 above provides the basis for estimating the volume of media potentially requiring remediation and for gauging the anticipated chemical or radionuclide concentration or activity gradient.

Consistent with the NCP (FR 55, No. 46) preliminary remediation goals for carcinogens will be established at a 1×10^{-6} excess cancer risk point of departure. Preliminary remediation goals may be revised, as the FS evolves, to a different risk level based on the consideration of appropriate factors including, but not limited to exposure, uncertainty, and technical factors.

4.2.1.2 Identify General Response Actions

General response actions that may prove appropriate at the site were identified in Section 2.5. These actions were identified in order to determine data gaps to be addressed in RI activities. For each response action, potentially applicable remedial technologies were identified. These are also presented in Section 2.5. As the Phase II RFI/RI progresses, additional potentially applicable technologies will likely be identified.

4.2.1.3 Screening of Technology Types and Process Options

During screening, the broad expanse of potentially applicable technology types will be narrowed by eliminating those technologies that are not technically implementable. Based on contaminant concentrations and other site-specific information contained in the Phase II RFI/RI, non-implementable technology types will be screened and eliminated from further consideration.

Technology process options for each retained technology type will then be screened in order to select a representative process option for each technology type that is technically implementable. Process options are compared and eliminated based on their effectiveness relative to other processes within the same technology type. The screening is based on the volume of media to be treated, achievement of remediation goals, potential impacts on human health and the environment, and the proven performance and reliability of the option considering the contaminants and site characteristics. In addition to effectiveness, the process options will also be evaluated based on administrative feasibility and relative cost. Results of treatability studies and geotechnical analyses will also be used to evaluate effectiveness, as appropriate.

4 2 1 4 Remedial Alternatives Development and Screening

To develop alternatives, response actions and the process options that are representative of the various technology types for each medium will be combined to form alternatives for the operable unit. In general, more than one response action is applicable to each medium. Response actions and process options will be assembled based primarily on medium-specific considerations and implementability. Descriptions of each alternative will be developed for inclusion in the CMS/FS report.

The response actions outlined in Table 2-17 must be applied to the potential exposure pathways that will be identified for OU No. 2. The response actions can individually be capable of providing control over all or some of the potential pathways. Partially effective response actions can be combined to form complementary sets of response actions that provide control over all pathways. In general terms, potential human exposure may be avoided by prevention of contaminant release, transport, and/or contact. Thus, application of the response actions may be considered at three different points in each potential exposure pathway: (1) at the point where the contaminant could be released from the source, (2) in the transport medium, and (3) at the point where the contact with the released contaminant could be prevented.

During alternative screening, the developed alternatives will be evaluated to ensure that they protect human health and welfare and the environment from each potential pathway of concern at the operable unit. Treatment rates will be identified, and the size and configuration of on-site extraction and treatment systems or containment structures will be developed. The time frame in which treatment, containment or removal can achieve remediation goals will be determined. Lastly, spatial requirements for treatment units, containment structures, staging of construction materials, excavated wastes, etc. will be determined. If there are off-site actions such as surface water discharge, a regulatory review will be conducted to determine permit and compliance requirements. Alternatives will then be evaluated in order to differentiate them with respect to effectiveness, implementability and cost.

Effectiveness is an evaluation of the protectiveness of human health and the environment achieved by a remedial alternative action during construction and implementation, and after the response objectives have been met. Evaluation of effectiveness in the short term is based on protection of the community and workers, impacts to the environment, and the time required to meet remedial response objectives. Long-term evaluation of effectiveness addresses the risk remaining to human health and the environment and is based on the percentage of permanent destruction, decreased mobility, and/or reduction in volume of toxic compounds achieved after response objectives have been met.

Implementability is a measure of both the technical and administrative feasibility of constructing, operating and maintaining a remedial action alternative. It is used during screening to evaluate the combinations of process

options with respect to the site-specific conditions. Technical feasibility refers to the ability to construct, reliably operate and comply with action-specific (technology-specific) requirements in order to complete the remedial action. Administrative feasibility refers to the ability to obtain required permits and approvals, to obtain the necessary services and capacity for treatment, storage and disposal of hazardous wastes, and to obtain essential equipment and technical expertise.

Cost estimates for screening will be derived from cost curves, generic unit costs, vendor information, conventional cost estimating guides and prior estimates made for Rocky Flats and similar sites, with modifications made for Rocky Flats Plant conditions. Absolute cost accuracy is not necessary. The cost estimates for the alternatives, however, will have the same relative accuracy for comparison and screening. The cost estimating procedures used during screening are similar to those that will be used during the later detailed alternatives analysis. The later detailed analysis, however, will receive more in-depth and detailed cost estimates of the components of each alternative. The screening cost estimates will include capital, operating, and maintenance costs. The operating and maintenance costs will be calculated for the lifetime of the treatment unit operation at the site. Present worth cost analysis will be used for alternatives in order to make the costs for the various alternatives comparable.

Alternatives with the most favorable results from the composite evaluation will be retained for further scrutiny during the detailed analysis. Not more than ten alternatives will be retained for detailed analysis (including containment and no action). At that time, it may be determined that additional site-specific information or technology-specific treatability studies are necessary for an objective detailed analysis. Also, it will be necessary to identify and verify the action-specific ARARs that each respective alternative will be required to meet.

4.2.2 Task 10 - Detailed Analysis of Remedial Alternatives

The detailed analysis is not a decision-making process, but it is the process of analyzing and comparing relevant information in order to select a remedial action. Each alternative will be assessed against nine NCP evaluation criteria, and the assessments will be compared to identify the key tradeoffs among the alternatives. Assessment against the nine evaluation criteria is necessary for the CMS/FS and the subsequent Record of Decision (ROD)/Corrective Action Decision (CAD) to comply with the requirements of CERCLA/RCRA. The nine evaluation criteria are described below:

- Overall Protection of Human Health and the Environment

The alternatives will be individually analyzed to determine if the alternative provides adequate protection of human health and the environment. The protectiveness evaluation focuses on

how the risks posed by each pathway are being eliminated, reduced or controlled by treatment, engineering or institutional measures

- **Compliance with ARARs**

Each alternative will be analyzed to determine whether it will comply with all state and federal ARARs that have been identified. The analysis will address compliance with chemical-specific, location-specific and action-specific ARARs in accordance with the NCP. If an alternative will not comply with an ARAR, the CMS/FS report will propose a basis for justifying a waiver, if appropriate.

- **Long-Term Effectiveness and Permanence**

This criterion assesses the risks that are left at the site after the response objectives have been met. The risks associated with any remaining untreated wastes or treatment residuals will be evaluated. For each alternative, the magnitude of the residual risk, and the reliability and adequacy of the controls used to manage untreated wastes and treatment residuals will be addressed.

- **Reduction of Toxicity, Mobility or Volume Through Treatment**

This criterion evaluates the statutory preference of selecting remedial actions that permanently reduce toxicity, mobility or volume of the hazardous materials. Factors evaluated for each alternative will include the proposed treatment process and the materials treated, the quantity of materials to be treated or destroyed, and how the primary hazardous threat will be addressed, the estimated degree of the reduction in toxicity, mobility or volume that will be achieved, the extent to which the treatment will be irreversible, the type and quantity of treatment residuals that will remain following treatment, and a determination if the alternative will comply with the statutory preference for treatment.

- **Short-Term Effectiveness**

Short-term effectiveness refers to the effects an alternative may have during the construction and implementation phases until the cleanup objectives have been achieved. Alternatives will be evaluated to determine the effects on human health and the environment during implementation. Each alternative will be assessed against the following factors: protection of the community and workers during the remedial action, environmental impacts, and the time required to achieve the remedial action objectives.

- **Implementability**

This criterion assesses the technical and administrative feasibility of implementing an alternative, and the availability of the necessary services and materials. The following factors will be analyzed during the implementability assessment: the technical feasibility of construction and operation, the reliability of the technology, the practicability of employing additional remedial actions, the ability to monitor the effectiveness of the remedial action, administrative coordination with other offices and agencies, the availability of adequate off-site hazardous (or mixed) waste treatment, storage and disposal, and the availability of equipment, expertise and other services and materials.

- **Costs**

An in-depth cost estimate will be conducted, and, if necessary, a cost sensitivity analysis will be prepared to evaluate costing assumptions. Capital costs include direct construction costs, indirect non-construction costs, and overhead costs. Operating and maintenance costs are

incurred after construction in order to operate the remedial action on a continuous basis until the remedial action objectives have been achieved CMS/FS cost estimates are expected to be within an accuracy range of minus 30 percent to plus 50 percent If this accuracy cannot be achieved, it will be stated in the CMS/FS report

A cost sensitivity analysis may be conducted to determine the effect that specific cost assumptions have on the total estimated cost of an alternative The cost assumptions will be based on site-specific data, technological operating data, etc , although the assumptions will be subject to varying degrees of uncertainty depending on the accuracy of the data

- **State Acceptance**

This criterion addresses the state's administrative and technical issues and concerns with each of the alternatives

- **Community Acceptance**

Community acceptance addresses the public's concerns and issues with each of the alternatives

The CMS/FS report will contain a narrative discussion of each alternatives evaluation against the nine criteria The narrative will describe how each alternative addresses the technical treatability issues, long-term and short-term effectiveness, costs, protection of human health and the environment, compliance with ARARs, etc Once the alternatives have been described, a comparative analysis will be conducted to evaluate the relative performance of each alternative The relative advantages and disadvantages of each alternative with respect to the other alternatives will be determined in order to assess the key tradeoffs that must be made in selecting a remedial action A candidate alternative must generally attain the primary objectives of compliance with ARARs and overall protection of human health and the environment in order for it to be eligible for selection as the remedial action A narrative discussion of the alternatives comparison describing the tradeoffs, and the benefits and detriments of each alternative in comparison to the others will be included in the CMS/FS report

Following completion of the CMS/FS process, the results of the detailed alternatives comparison and risk management will be used as the rationale for selecting a preferred alternative and a remedial action

4 2 3 Task 11 - Feasibility Study Report

The CMS/FS Report will discuss and present the results of the feasibility study The results of the detailed alternatives comparison will be used as the rationale for selecting a preferred alternative and a remedial action Although the purpose of the FS report and process is not to select a remedial action, it will present and evaluate the alternatives in sufficient detail in order to objectively consider all significant issues and select a feasible, cost-effective, and defensible remedial action The report will include sections describing site background, nature and extent of problem, results of the RFI/RI, risk assessment and environmental evaluation,

identification, screening and detailed evaluation of remedial alternatives, and the recommended remedial actions. This task includes preparation of a Draft CMS/FS report, and preparation of a Final CMS/FS that incorporates EPA and CDH comments. A preliminary outline of the CMS/FS report is shown in Table 4-2.

As with the RFI/RI, some portions of the CMS/FS may be conducted separately for the bedrock and alluvial components of the site. It is likely that remediation requirements will not be the same for the bedrock as for upper HSU. However, both the bedrock and alluvium will be addressed during the CMS/FS and only one CMS/FS report will be prepared.

TABLE 4-2

CMS/FS REPORT FORMAT

Executive Summary

1 0 Introduction

1 1 Purpose and Organization of Report

1 2 Background Information (summarized from RI Report)

1 2 1 Site Description

1 2 2 Site History

1 2 3 Nature and Extent of Contamination

1 2 4 Contaminant Fate and Transport

1 2 5 Baseline Risk Assessment

2 0 Identification and Screening of Technologies

2 1 Introduction

2 2 Remedial Action Objectives

Present the development of remedial action objectives for each medium of interest (i.e., ground water, soil, surface water, air, etc.)

For each medium, the following should be discussed

- Contaminants of interest
- Allowable exposure based on risk assessment (including ARARs)
- Development of remediation goals

2 3 General Response Actions

For each medium of interest, describes the estimation of areas or volumes to which treatment, containment, or exposure technologies may be applied

2 4 Identification and Screening of Technology Types and Process Options - For each medium of interest described

2 4 1 Identification and Screening of Technologies

2 4 2 Evaluation of Technologies and Selection of Representative Technologies

3 0 Development and Screening of Alternatives

3 1 Development of Alternatives

Describes rationale for combination of technologies/media into alternatives **Note** This discussion may be by medium or for the site as a whole

3 2 Screening of Alternatives

3 2 1 Introduction

3 2 2 Alternative 1

3 2 2 1 Description

3 2 2 2 Evaluation

3 2 3 Alternative 2

3 2 3 1 Description

3 2 3 2 Evaluation

3 2 4 Alternative 3

Sheet 1 of 2

TABLE 4-2 (Continued)
CMS/FS REPORT FORMAT

4 0 Detailed Analysis of Alternatives

4 1 Introduction

4 2 Individual Analysis of Alternatives

4 2 1 Alternative 1

4 2 1 1 Description

4 2 1 2 Assessment

4 2 2 Alternative 2

4 2 2 1 Description

4 2 2 2 Assessment

4 2 3 Alternative 3

4 3 Comparative Analysis

Bibliography

Appendices

Sheet 2 of 2

PHASE II RFI/RI FIELD SAMPLING PLAN

The overall objectives of the Phase II RFI/RI is to characterize in detail the nature and extent of soil contamination and plumes within the upper HSU. The specific goals of the RFI/RI (EPA, 1988a) include the following

- Characterize site physical features
- Define contaminant sources
- Describe contaminant fate and transport
- Provide a baseline risk assessment
- Provide an adequate body of data for the Feasibility Study and the Record of Decision (ROD)

The purpose of Section 5.0 is to provide a detailed Field Sampling Plan (FSP) which will realize the goals and the data quality objectives described in Section 3.0

5.1 FIELD SAMPLING RATIONALE

A four step approach will be used for the FSP

- | | |
|------------|--|
| Step One | Review of Existing Data |
| Step Two | Conduct Preliminary and Screening Study Activities |
| Step Three | Conduct Detailed Field Sampling Program |
| Step Four | Conduct Field and Analytical Laboratory Testing Programs |

5.1.1 Step One - Review of Existing Data

This initial step consists of collecting, reviewing, and analyzing the Phase I RI report, previous drafts of the Phase II work plan, regulatory agency comments on the draft work plans, responses to these comments, and other relevant documents, e.g., data, plans, and reports from adjacent or on-going Operable Unit investigations. This has been performed in preparation of this work plan. The current understanding of the nature and extent of contamination at OU No. 2 is based on all available chemical data, however, only data collected through the summer of 1989 are presented. More recent analytical data are not included in this work plan because they are still in the process of being validated and do not significantly alter the site conceptual model. The existing data set also includes an electromagnetic geophysical survey of all the IHSSs (see Phase I RFI/RI Report).

5 1 2 Step Two - Preliminary Field and Screening Study Activities

This second step involves preliminary field and screening study activities in advance of implementing the detailed FSP (Step 3). These include surveying of borehole and IHSS locations, FIDLER monitoring surveys, air monitoring, surface soil and environmental evaluation reconnaissance visits, mobilization for the drilling and sampling program, setting up temporary waste handling facilities, temporary sample storage facilities, and establishment of health and safety procedures. SOPs have been prepared for these activities where appropriate.

5 1 3 Step Three - Detailed Field Sampling Activities

The third step is to conduct detailed field studies that include

- Plume characterization, well installation, and sampling
- Source characterization borehole sampling and well installation/sampling
- Surficial soil sampling
- Environmental evaluation study

Sections 5 2, 5 3, and 5 4 describe the details of the first three activities, respectively. The environmental evaluation study is described in Section 6 0. The environmental evaluation will be conducted as an integrated study with the environmental evaluations for OU No. 1, OU No. 5, and OU No. 6. The results relevant to OU No. 2 of this integrated study will be incorporated into the OU No. 2 Phase II RFI/RI Report.

5 1 4 Step Four - Field and Analytical Tests

This last step includes all of the testing activities (Section 5 5) such as field screening tests for volatile organics and radioactivity, hydraulic pumping and tracer tests, and chemical testing of soil and water samples. All data obtained from these activities will be compiled in the EG&G Rocky Flats Environmental Data System (RFEDS) data base.

5 2 GROUND-WATER PLUME CHARACTERIZATION PROGRAM

The purpose of the ground-water plume characterization program is to delineate the horizontal and vertical extent of volatile organic, semi-volatile organic, inorganic, and radiological contaminants in ground water within the upper HSU. The areal scope of the investigation extends laterally to the seeps within South Walnut Creek and Woman Creek, and vertically into the Number One Arapahoe Sandstone subcrop. Approximately 130

monitor wells are proposed for this activity. Monitor wells are proposed for the alluvial and bedrock (weathered bedrock and subcrop sandstones) systems of the upper HSU.

Presented below are proposed monitor well locations and the rationale for further characterization of ground-water flow and quality in the upper HSU at OU No. 2 (see Tables 5-1 and 5-2). Bedrock ground-water investigations for the lower HSU at OU No. 2 are proposed in the Phase II RFI/RI (bedrock) Work Plan.

The following discussion presents borehole and monitor well locations as if one well will be installed at each location. However, the number of wells per location and the screened interval of each well will be determined based upon the saturated thickness. If the encountered saturated thickness is 10 feet or less, a single well will be installed, and the screened interval will extend from five feet above the water table to the base of the water bearing zone. Two wells will be installed if the saturated thickness is greater than 10 feet and less than 30 feet. One of the two wells will be completed at the water table as described above, and a second well will be completed across the lower part of the water bearing unit. If a saturated thickness greater than 30 feet is encountered, a third well will be completed at the base of the water bearing unit. All plume characterization boreholes for installation of monitor wells will be drilled, logged, and sampled for lithologic description purposes only. The monitor wells will be completed in accordance with the Rocky Flats ER Program SOP (EG&G, 1990i). After these plume characterization monitor wells have been developed, ground-water samples will be collected for analytical chemical tests on a quarterly basis to record change in the ground-water contamination plume.

5.2.1 Proposed Borehole and Monitor Wells in Alluvium

Boreholes and monitor wells are proposed for each of the following IHSS Areas. Table 5-1 includes a more detailed summary of each borehole and monitor well, and drilling locations are shown on Plate 1.

- 903 Pad Area - 18 wells
- Mound Area - 13 wells
- East Trenches Area - 7 wells

5.2.1.1 903 Pad Area

Eighteen proposed alluvial monitor wells will further define the lateral extent of saturation, the potentiometric surface, and the extent of volatile organics in the shallow ground-water system east and southeast of the 903 Pad Area (Plate 1). Three wells (1-91, 2-91, and 3-91) will be completed in Rocky Flats Alluvium east of the 903 Drum Storage Site to define the extent of volatile organics in alluvial ground water and to characterize alluvial ground water flow. Likewise, eight alluvial wells (4-91 through 9-91, 105-91, and 106-91) will be completed in

TABLE 5-1
PROPOSED PHASE II WELLS
FOR PLUME CHARACTERIZATION

WELL OR BOREHOLE NO	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g s)	ANTICIPATED SCREENED INTERVAL
1 91	Volatile organic plume definition downgradient (east) of 903 Pad and Mound Areas	25	5-25 ²
2-91	Volatile organic plume definition downgradient (east) of 903 Pad and Mound Areas	15	5-15
3-91	Volatile organic plume definition downgradient (east) of 903 Pad and Mound Areas	15	5-15
4-91	Volatile organic plume definition downgradient (southeast) of 903 Pad and Mound Areas Extent of saturated colluvium	15	5-15
5-91	Volatile organic plume definition downgradient (southeast) of 903 Pad Extent of saturated colluvium	10	5-10
6 91	Volatile organic plume definition downgradient (southeast) of 903 Pad Extent of saturated colluvium	10	5-10
7-91	Volatile organic plume definition downgradient (southeast) of 903 Pad Extent of saturated colluvium	10	5-10
8-91	Volatile organic plume definition downgradient (southeast) of 903 Pad Extent of saturated colluvium	10	5-10
9-91	Volatile organic plume definition downgradient (south) of 903 Pad Extent of saturated colluvium	10	5-10
10-91	Volatile organic plume definition downgradient (south) of the 903 Pad Area Ground water/surface water interaction at SID	20	5-20 ²
11-91	Volatile organic plume definition downgradient (southeast) of the 903 Pad Area Ground water/surface water interaction at SID	20	5-20 ²
12 91	Volatile organic plume definition downgradient (southeast) of the 903 Pad Area Ground water/surface water interaction at SID	20	5-20 ²

TABLE 5-1 (Continued)

**PROPOSED PHASE II WELLS
FOR PLUME CHARACTERIZATION**

WELL OR BOREHOLE NO	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
13-91	Determine extent of elevated inorganics in well 29-87 Ground water/surface water interaction at SID	20	5-20 ²
14-91	Woman Creek valley fill alluvial ground water Upgradient of Pond C-1 and downgradient of well 64-86	10	5-10
15-91	Woman Creek valley fill alluvial ground water upgradient of 65-86	10	5-10
16 91	Woman Creek valley fill alluvial ground water downgradient of 65-86	10	5-10
17-91	Ground-water quality upgradient (west) of Operable Unit No 2	15	5-15
18-91	Ground-water quality and extent of saturation adjacent to possible Pallet Burn Site	15	5-15
19-91	Ground-water quality downgradient (north) of Pallet Burn Site	10	5-10
20-91	Ground-water quality downgradient (south) of Oil Burn Pit Site	10	5-10
21 91	Ground-water quality downgradient (south) of Mound Site	10	5-10
22-91	Ground-water quality downgradient of Trench T-1 and upgradient of Mound to differentiate between sources	25	5-25 ²
23-91	Ground-water quality upgradient of Trench T-1 and downgradient of the 903 Pad to differentiate between sources	25	5-25 ²
24-91	Volatile organic plume definition downgradient (northeast) of Mound Area	10	5-10
25 91	Volatile organic plume definition downgradient (east) of 903 Pad and Mound Areas	15	5-15
26 91	Volatile organic plume definition downgradient (east) of Mound Area	20	5-20 ²
27 91	Volatile organic plume definition downgradient (north) of Mound Area	20	5-20 ²
28-91	Volatile organic plume definition downgradient (north) of Mound Area	10	5-10

TABLE 5-1 (Continued)

**PROPOSED PHASE II WELLS
FOR PLUME CHARACTERIZATION**

WELL OR BOREHOLE NO.	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
29-91	Volatile organic plume definition downgradient (northeast) of Mound Area	15	5-15
30-91	Volatile organic plume definition downgradient (northeast) of Mound Area	10	5-10
31-91	Volatile organic plume definition downgradient (northeast) of Mound Area	15	5-15
32-91	Volatile organic plume definition downgradient (northeast) of Mound Area	15	5-15
33-91	Volatile organic plume definition downgradient (northeast) of Mound Area	15	5-15
34-91	Volatile organic plume definition downgradient (northeast) of Mound Area	15	5-15
35-91	Volatile organic plume definition downgradient (north) of Trench T-3 Replace well 3-74	10	5-10
36-91	Ground-water quality downgradient of Trench T-3 and upgradient of Trench T-4 to differentiate between sources	10	5-10
37-91	Volatile organic plume definition downgradient (south) of Trench T-3	15	5-15
38-91	Ground water quality downgradient (south) of Trench T-4 and upgradient (north) of Trench T-11 to differentiate between sources	15	5-15
39-91	Ground-water quality downgradient (south of Trench T-4) and upgradient (north) Trench T-10 to differentiate between sources	15	5-15
40-91	Volatile organic plume definition downgradient (south) of Trench T-10	20	5-20 ²
41-91	Volatile organic plume definition downgradient (south) of Trench T-11	20	5-20 ²
42-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10
43-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10

TABLE 5-1 (Continued)

**PROPOSED PHASE II WELLS
FOR PLUME CHARACTERIZATION**

WELL OR BOREHOLE NO	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
44-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	20	5-20 ²
45-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10
46 91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10
47-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10
48-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10
49 91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	10	5-10
50 91	Ground-water quality upgradient of southern East Trenches	25	5-25 ²
51-91	Ground-water quality downgradient (north) of Trench T-9	30	5-30 ²
52-91	Ground-water quality downgradient (south) of Trench T-9	40	5-40 ²
53 91	Ground-water quality downgradient (north) of Trench T 5	40	5-40 ²
54 91	Ground-water quality downgradient (east) of Trenches T-5, T-6, and T-7 Evaluate influence of East Spray Field Sites on ground-water flow and quality	40	5-40 ²
55 91	Ground-water quality downgradient (south) of Trench T 7 and upgradient (north) of Trench T-8 to differentiate between sources	40	5-40 ²
56-91	Volatile organic plume definition downgradient (southeast) of East Trenches Area	40	5-40 ²
57 91	Volatile organic plume definition downgradient (southeast) of East Trenches Area	40	5-40 ²

TABLE 5-1 (Continued)

**PROPOSED PHASE II WELLS
FOR PLUME CHARACTERIZATION**

WELL OR BOREHOLE NO.	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
58-91	Volatile organic plume definition downgradient (southeast) of East Trenches Area	40	5-40 ²
59-91	Volatile organic plume definition downgradient (southeast) of East Trenches Area	40	5-40 ²
60-91	Volatile organic plume definition downgradient (southeast) of East Trenches Area	40	5-40 ²
61-91	Volatile organic plume definition downgradient (southeast) of East Trenches Area	40	5-40 ²
62-91	Evaluate influence of East Spray Field Sites on ground-water flow and quality	40	5-40 ²
63-91	Evaluate influence of East Spray Field Sites on ground-water flow and quality	40	5-40 ²
64-91	Evaluate influence of East Spray Field Sites on ground-water flow and quality	40	5-40 ²
65-91	Evaluate influence of East Spray Field Sites on ground-water flow and quality	40	5-40 ²
66-91	Evaluate influence of East Spray Field Sites on ground-water flow and quality	40	5-40 ²
67-91	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area	40	5-40 ²
68-91	Ground-water quality southeast of East Trenches Area	10	5-10
105-91	Ground-water quality downgradient of 913 Pad and Reactive Metal Destruction Site	10	5-10
107-91	Ground-water quality downgradient (northeast) of East Trenches Area	40	5-40 ²
108-91	Ground-water quality downgradient (northeast) of East Trenches Area	40	5-40 ²
109-91	Volatile organic plume definition and extent of saturation downgradient (northeast) of East Trenches Area	30	5-30
110-91	Volatile organic plume definition and extent of saturation downgradient (northeast) of East Trenches Area	30	5-30
111-91	Volatile organic plume definition and extent of saturation downgradient (northeast) of East Trenches Area	30	5-30

TABLE 5-1 (Continued)
PROPOSED PHASE II WELLS
FOR PLUME CHARACTERIZATION

WELL OR BOREHOLE NO.	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
112-91	Volatile organic plume definition and extent of saturation downgradient (northeast) of East Trenches Area	8	3-8
113-91	Volatile organic plume definition and extent of saturation downgradient (northeast) of East Trenches Area	8	3-8
		Total Proposed Wells for Plume Characterization 41 + (2 x 16) + (3 x 19)	= <u>130</u>
		41 single wells 16 double well clusters 19 triple well clusters	

Notes

- ¹ Ground-water quality and lithologic data will provide better characterization of the ground-water exposure pathway in support of the baseline risk assessment
- ² If the encountered saturated thickness is greater than 10 feet, a well cluster will be installed as explained in Section 5.1.1
- g s ground surface

TABLE 5-2

**PROPOSED PHASE II WELLS AND BOREHOLES
FOR SOURCE CHARACTERIZATION**

WELL OR BOREHOLE NO	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
69-91/BH0191	Characterization upgradient (west) of 903 Pad	15	5-15
70-91/BH0291	Ground-water quality beneath 903 Pad Source characterization 903 Pad	15	5-15
BH0391	Source characterization 903 Pad	N/A	N/A
71-91/BH0491	Ground-water quality beneath 903 Pad Source characterization 903 Pad	15	5-15
72 91/BH0591	Ground-water quality downgradient (south) of 903 Pad Soil characterization adjacent to 903 Pad ²	15	5-15
73 91/BH0691	Ground-water quality downgradient (north) of 903 Pad Soil characterization adjacent to 903 Pad	20	5-20 ²
BH0791	Source characterization 903 Pad	N/A	N/A
74 91/BH0891	Ground-water quality beneath 903 Pad Source characterization 903 Pad	20	5-20 ²
BH0991	Source characterization 903 Pad	N/A	N/A
BH1091	Source characterization 903 Pad	N/A	N/A
75 91/BH1191	Ground-water quality downgradient (east) of 903 Pad Soil characterization adjacent to 903 Pad	20	5-20 ²
76-91/BH1291	Ground-water quality downgradient (east) of 903 Pad Soil characterization adjacent to 903 Pad	20	5-20 ²
77 91/BH1391	Ground-water quality downgradient (south) of 903 Pad Soil characterization adjacent to 903 Pad	20	5-20 ²
78 91/BH1491	Ground-water quality beneath Trench T-2 Source characterization Trench T-2	10	5-10
BH1591	Source characterization Trench T-2 Extent of soil contamination	N/A	N/A
79-91/BH1691	Ground-water quality downgradient (south) of 903 Pad and upgradient of Trench T-2 (north) to differentiate between sources	10	5-10
BH1791	Source characterization Trench T-2 Extent of soil contamination	N/A	N/A
BH1891	Source characterization Trench T-2 Extent of soil contamination	N/A	N/A
80 91/BH1991	Ground water quality downgradient south of Trench T 2 Extent of soil contamination	10	5-10

Sheet 1 of 3

TABLE 5-2 (Continued)

**PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
FOR SOURCE CHARACTERIZATION**

WELL OR BOREHOLE NO.	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft below g.s.)	ANTICIPATED SCREENED INTERVAL
81-91/BH2091	Source characterization Reactive Metal Destruction Site	10	5-10
82-91/BH2191	Ground-water quality downgradient (south) of Reactive Metal Destruction Site	10	5-10
83-91/BH2291	Source characterization Reactive Metal Destruction Site	N/A	N/A
84-91/BH2391	Ground-water quality downgradient of Reactive Metal Destruction Site Extent of soil contamination	10	5-10
85-91/BH2491	Ground-water quality downgradient of 903 and Reactive Metal Destruction Site Extent of soil contamination	10	5-10
86 91/BH2591	Ground-water quality beneath Mound Site Source characterization	25	5-25 ²
87-91/BH2691	Ground-water quality beneath Mound Site Source characterization	25	5-25 ²
BH2791	Extent of soil contamination Mound Site	N/A	N/A
BH2891	Investigation possible Pallet Burn Site location	N/A	N/A
88-91/BH2991	Ground-water quality beneath Trench T-3 Source characterization	20	10-20
89-91/BH3091	Ground-water quality beneath Trench T-4 Source characterization	20	10-20
91-91/BH3191	Ground-water quality beneath Trench T-4 Source characterization	25	10-25 ²
91-91/BH3291	Ground-water quality beneath Trench T-11 Source characterization	25	10-25 ²
92-91/BH3391	Ground-water quality beneath Trench T-11 Source characterization	25	10-25 ²
93 91/BH3491	Ground-water quality beneath Trench T-9 Source characterization	40	10-40 ²
94-91/BH3591	Ground-water quality beneath Trench T-5 Source characterization	40	10-40 ²
95 91/BH3691	Ground-water quality beneath Trench T-5 Source characterization	40	10-40 ²

TABLE 5-2 (Continued)

**PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
FOR SOURCE CHARACTERIZATION**

WELL OR BOREHOLE NO.	PURPOSE ¹	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s.)	ANTICIPATED SCREENED INTERVAL
96-91/BH3791	Ground-water quality beneath Trench T-6 Source characterization	40	10-40 ²
97-91/BH3891	Ground-water quality beneath Trench T-7 Source characterization	40	10-40 ²
98 91/BH3991	Ground-water quality beneath Trench T-7 Source characterization	40	10-40 ²
99-91/BH4091	Ground-water quality beneath Trench T-8 Source characterization	40	10-40 ²
100-91/BH4191	Ground-water quality beneath Trench T-8 Source characterization	40	10-40 ²
101-91/BH4291	Ground-water quality beneath the East Spray Field Source characterization	40	5-40 ²
102-91/BH4391	Ground-water quality beneath the East Spray Field Source characterization	45	5-45 ²
103 91/BH4491	Ground-water quality beneath the East Spray Field Source characterization	40	5-40 ²
104 91/BH4591	Ground-water quality beneath the East Spray Field Source characterization	40	5-40 ²
106-91/BH4691	Ground-water quality beneath Gas Detoxification Site Source characterization	10	5-10

Total Proposed Boreholes	<u>46</u>
Total Proposed Monitor Wells for Source Characterization	
15 + (2 x 18) + (3 x 4) =	<u>63</u>
15 single wells 18 double well clusters 4 triple well clusters	
Grand Total	<u>= 109</u>

Notes

- ¹ Ground water and soil analyses will be used to define the range and maximum concentration of contamination in support of the baseline risk assessment
- ² If the encountered saturated thickness is greater than 10 feet, a well cluster will be installed as explained in Section 5.1.1
- ³ In the context of source characterization, the term "Soil" means alluvial and/or weathered bedrock materials
- g s ground surface

Sheet 3 of 3

colluvium southeast of the 903 Pad Area for plume delineation. Alluvial wells 10-91, 11-91, and 12-91 will be drilled along the northern berm of the SID and completed in the berm to monitor the quality of ground water adjacent to the ditch. Well 13-91 will be located on the southern berm of the ditch across from 29-87 to evaluate the elevated inorganics detected in well 29-87, and the relationship between the SID and alluvial ground-water flow and quality.

Volatile organics have not been detected in Woman Creek valley fill alluvium downgradient of the 903 Pad Area in well 65-86. However, inorganic compounds appear elevated in this well, and PCE was detected at $8\text{J } \mu\text{g/l}$ in well 64-86 during one sampling event (second quarter 1989). Thus, three additional wells will be installed along Woman Creek to further characterize the valley fill alluvium. Well 14-91 will be completed west (upgradient) of Pond C-1, well 15-91 will be completed west (upgradient) of 65-86 and east (downgradient) of Pond C-1, and well 16-91 will be drilled east (downgradient) of 65-86 but west (upgradient) of Pond C-2.

5 2 1 2 Mound Area

Several new alluvial monitor wells are proposed for the Mound Area. The current upgradient well (43-86) appears to be impacted by the 903 Drum Storage Site, so another upgradient alluvial well is needed. Proposed well 17-91 will be installed in Rocky Flats Alluvium west of 43-86 and the 903 Pad Area to serve as an upgradient well.

Four wells will be located downgradient of the Oil Burn Pit No. 2 Site and the Pallet Burn Site to monitor ground water from these sites. As these IHSSs are within the PSZ fence, well installation downgradient of them is difficult. Wells will be placed as close as possible to the IHSSs. Well 18-91 will be installed adjacent to the Western Pallet Burn Site, and wells 19-91 and 20-91 will be installed downgradient of this site inside the PSZ fence. Well 21-91 will be installed downgradient of the Oil Burn Pit No. 2 Site, outside of the PSZ fence.

Thirteen wells will be located downgradient of Trench T-1 and the Mound Site. Wells 22-91 and 23-91 will be installed adjacent to and downgradient of Trench T-1. Data from well 22-91, located between the trench and the Mound Site, will differentiate contamination from these two sources and assist in characterization of the ground-water pathway in this location. In addition, three wells (24-91, 25-91, and 26-91) will be installed downgradient of the Mound Site and Trench T-1 to the east, to evaluate the extent of volatile organic contamination in this direction. Eight wells (27-91 through 34-91) will be completed north and northeast of the Mound Area to characterize ground-water flow and quality toward South Walnut Creek.

5 2 1 3 East Trenches Area

Seven new alluvial boreholes and wells will be drilled within the northern trench area to characterize ground-water quality and flow. Wells 35-91, 36-91, and 37-91 will be installed downgradient of Trench T-3 to the north, east, and south, respectively. These proposed wells will assist in differentiating between Trenches T-3 and T-4 as the source of volatile organics in well 36-87. Wells 38-91 and 39-91 will be constructed between Trenches T-3/T-4 and T-11/T-10 in an attempt to differentiate the two groups of trenches as contaminant sources. Alluvial ground-water flow in this area is to the southeast toward Trenches T-10 and T-11. Wells 40-91 and 41-91 will be located southeast of Trenches T-11 and T-10 to further characterize the extent of volatile organics in alluvial ground water.

Downgradient of the northern East Trenches toward South Walnut Creek, eight new wells will be installed to evaluate saturated conditions and to delineate the plume north of the Trenches (proposed wells 42-91 through 49-91). Seven new alluvial wells will be installed downgradient (northeast) of the East Trenches. These wells will be used to investigate the ground-water volatile organic contamination apparently present in the vicinity of well 39-86 (unvalidated). Wells 107-91 and 108-91 will be located upgradient of existing well 39-86 and downgradient of the East Trenches to aid in determining the source of the contamination. Proposed wells 109-91, 110-91, and 111-91 will be installed immediately downgradient of well 39-86, and wells 112-91 and 113-91 will be installed in valley fill alluvium at the plant boundary to better define the extent of contamination.

Eight new alluvial wells are proposed within the southern trenches, again, to help differentiate between these potential contaminant sources and define the extent of contamination and pathways within the upper HSU. Well 50-91 will be installed south of the northern trenches and west of the southern trenches to differentiate between these source areas. Wells 51-91 and 52-91 will be drilled adjacent to Trench T-9, and wells 53-91, 54-91, and 55-91 will bracket flow into and out of Trenches T-5, T-6, and T-7. In addition, well 55-91, located downgradient of Trenches T-5, T-6, and T-7 and upgradient of Trench T-8, will help differentiate these sites as contaminant sources. Wells 56-91 and 57-91 will be located downgradient (south and southeast) of Trench T-8.

Ten alluvial wells will be installed surrounding the southern East Trenches and the East Spray Field to monitor flow and quality of ground water exiting the area. These wells (58-91 through 67-91) will help delineate the southern and eastern extent of volatile organics plumes in Rocky Flats alluvial ground water. Well 68-91 will be located south of this line of wells and will be completed in colluvium to further characterize hydrogeologic conditions in this area.

5 2 2 Proposed Monitor Wells in Bedrock

Arapahoe sandstones, which subcrop within OU No. 2, are in hydraulic connection with surficial materials and are, thus, part of the upper HSU (Figure 2-15). During previous investigations, bedrock monitoring wells were installed adjacent to alluvial wells in the uppermost sandstone encountered. Some of these wells are completed in subcropping sandstone, and volatile organic contaminants have been detected in some wells as discussed in Section 2.0. In order to further characterize ground-water flow directions and ground-water quality within these shallow sandstones, additional bedrock monitor wells will be installed during the Phase II RFI/RI. The deeper confined bedrock units will be investigated during implementation of the Phase II (Bedrock) Work Plan. The interface between the alluvial and the bedrock field investigations is shown in Figure 1-1.

The placement of bedrock monitor wells in the upper HSU will be based on conditions encountered during alluvial well drilling. Alluvial wells will be drilled five feet into bedrock to locate subcropping sandstones. If a saturated subcropping sandstone greater than three feet in thickness is encountered within this five-foot interval, surface casing will be set, the boring will be advanced through the sandstone and a minimum of five feet into claystone or siltstone beneath the upper sandstone layer. A bedrock well will then be completed within this upper sandstone layer. A second boring will then be drilled adjacent to the bedrock well for installation of an alluvial well.

5 3 SOURCE CHARACTERIZATION PROGRAM

Boreholes will be drilled into IHSSs where access is feasible to characterize any waste materials remaining in place, and to assess the maximum contaminant concentrations in the alluvium and weathered bedrock directly beneath the sites. In addition, ground-water monitoring wells will be installed adjacent to selected boreholes to characterize ground-water quality directly beneath the sites. This section discusses those selected wells and boreholes which will be drilled for source characterization. Wells to be drilled outside of IHSSs for characterizing the extent of plume contamination are discussed in Section 5.2. Table 5-2 provides an overview of all proposed Phase II RFI/RI source characterization boreholes and wells which are shown on Plate 1. All drilling, sampling, and well installation will follow the Rocky Flats Plant ER Program SOP.

Boreholes to be drilled into IHSSs will extend from the ground surface to the base of weathered claystone bedrock. Continuous borehole samples will be collected for lithologic descriptions for the entire borehole depth. From this core, discrete samples will be submitted for laboratory chemical analyses every two feet from the ground surface to the water table. In addition, a discrete sample will be collected for chemical analysis at the water table. Core from saturated alluvial materials will not be submitted to the laboratory as the presence of water in this zone will affect interpretation of chemical results. In order to prevent alluvial ground

water from affecting weathered bedrock samples, surface casing will be grouted into the borehole through alluvial materials. Subsequent to grout hardening, the borehole will then be advanced through weathered bedrock with continuous sampling. Discrete samples from the core will be submitted to the laboratory for chemical analysis from two feet immediately below the casing, and every four feet thereafter to the base of weathering and a minimum of five feet into the weathered bedrock zone. To further characterize bedrock immediately beneath the sites, in situ packer tests will be performed in the weathered bedrock where conditions allow.

Alluvial and bedrock ground-water monitoring wells will also be installed to characterize ground-water quality directly beneath IHSSs. Wells will be drilled, sampled, and completed in accordance with the Rocky Flats ER Program SOP. The screened interval of all alluvial and bedrock monitor wells will depend on the saturated thickness. If the saturated thickness is 10 feet or less, a single well will be installed and the screened interval will extend from five feet above the water table to the base of the water-bearing zone. Two wells will be installed if the saturated thickness is greater than 10 feet and less than 30 feet. One of the two wells will be completed at the water table as described above, and a second well will be completed across the lower part of the water bearing unit. If a saturated thickness greater than 30 feet is encountered, a third well will be completed at the base of the water bearing unit. In addition, a bedrock well will be installed if a subcropping sandstone is encountered. Source characterization well locations are discussed in the following sections.

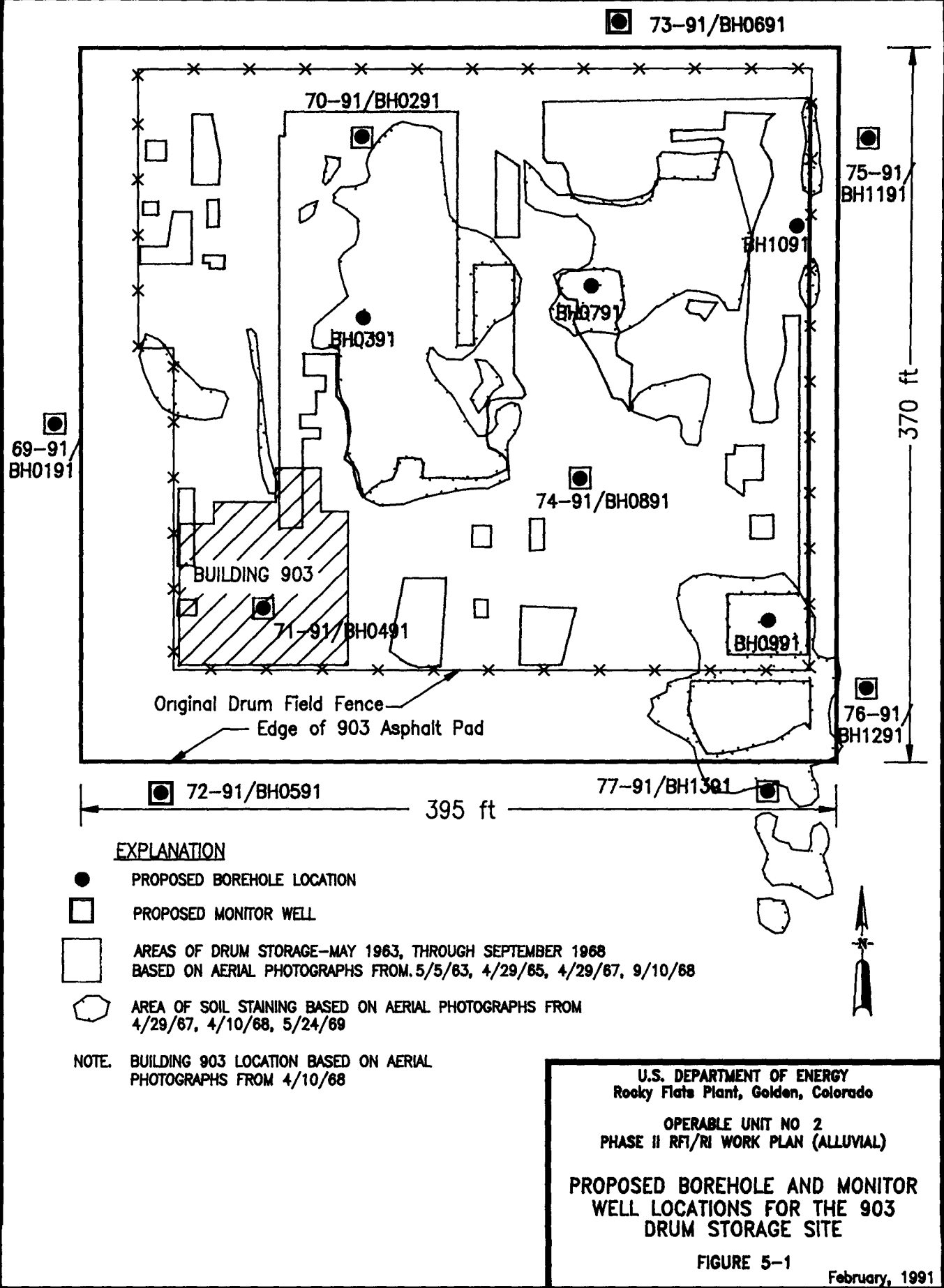
5.3.1 903 Pad Area

IHSSs of the 903 Pad Area are shown in Figure 1-5. Specific source sampling activities for sites within the 903 Pad Area are discussed below for the 903 Drum Storage Site, 903 Lip Site, Trench T-2 Reactive Metal Destruction Site, and Gas Detoxification Site.

903 Drum Storage Site (IHSS Ref. No. 112)

In order to characterize the vertical and horizontal extent of radionuclide and solvent contamination beneath the 903 Pad, 13 boreholes (BH0191 through BH1391) are proposed within and immediately adjacent to the site. These boreholes have been located in areas which contained drums as well as in areas which historically did not contain drums (Figure 5-1).

In order to characterize the ground water beneath and adjacent to the 903 Pad, alluvial monitoring wells 69-91 through 77-91 will be installed adjacent to boreholes BH0191, BH0291, BH0491, BH0591, BH0691, BH0891, BH1191, BH1291, and BH1391, respectively.



903 Lip Site (IHSS Ref No 155)

Boreholes will not be drilled specifically for source characterization of the 903 Lip Site as surficial radionuclides are the contaminants of concern. Therefore, surficial soil sampling and radionuclide analyses will be performed in the area. This sampling is discussed in Section 5.4.

Trench T-2 Site (IHSS Ref No. 109)

One alluvial well/borehole pair (78-91/BH1491) will be drilled through the east end of Trench T-2 to characterize the contents and dimensions of the site (Plate 1). Barrels are known to be present at the west end of the trench, so no borehole will be drilled in this area. Well 78-91 will be completed as a colluvial monitoring well in order to sample ground water directly beneath this site.

In addition to well/borehole 78-91/BH1491, boreholes BH1591, BH1691, BH1791, BH1891, and BH1991 will be drilled around Trench T-2 to verify its location, and to evaluate the extent of soil contamination in the area. Colluvial monitoring wells 79-91 and 80-91 will be installed adjacent to boreholes BH1691 and BH1991, respectively, to monitor water quality upgradient and downgradient of Trench T-2.

Reactive Metal Destruction Site (IHSS Ref No 140)

Three boreholes (BH2091, BH2191, and BH2291) will be drilled within the Reactive Metal Destruction Site to further characterize this source and the extent of soil contamination. Boreholes BH2391 and BH2491, downgradient of the site, will be drilled and sampled to evaluate the extent of soil contamination in the area. Colluvial monitoring wells 81-91 through 85-91 will be completed adjacent to boreholes BH2091 through BH2491, respectively, to monitor water quality within and downgradient of the site (Plate 1).

Gas Detoxification Site (IHSS Ref No 183)

A boring (BH4691) will be drilled within the Gas Detoxification Site to characterize the potential source. Colluvial monitor well 106-91 will be installed adjacent to borehole BH4691 to investigate ground-water quality beneath the site.

5 3 2 Mound Area

IHSSs within the Mound Area are identified on Figure 1-5. Proposed well and borehole locations are shown on Plate 1 and summarized in Table 5-2. Details of source characterization activities planned for sites within the Mound Area are provided below. These include the Mound Site, Trench T-1, Oil Burn Pit, and the Pallet Burn Site.

Mound Site (IHSS Ref No 113)

Boreholes BH2591 and BH2691, are proposed within the revised boundaries of the Mound Site to characterize soils and any remaining wastes. Alluvial monitoring wells 86-91 and 87-91 will be completed adjacent to boreholes BH2591 and BH2691, respectively, to monitor ground-water quality beneath the site. In addition, borehole BH2791 will be drilled and sampled downgradient of the Mound Site adjacent to existing wells 1-74 and 19-87. This hole will serve to characterize the nature and extent of soil contamination possibly associated with the high levels of PCE and TCE detected in well 1-74.

Trench T-1 Site (IHSS Ref No 108)

No boreholes are proposed within Trench T-1 because of the ubiquitous presence of barrels. However, additional alluvial ground-water monitoring wells are proposed adjacent to the trench as discussed in Section 5 2 1 2.

Oil Burn Pit No 2 Site (IHSS Ref No 153)

This site was removed in the 1970s and its location is currently covered by the PSZ fence which is inaccessible for security purposes. Therefore, no additional boreholes are proposed for source characterization of this site. Additional monitor wells upgradient and downgradient of the Oil Burn Pit Site are discussed in Section 5 2 1 2.

Pallet Burn Site (SWMU Ref No 154)

The western-most of the two possible locations for this site is located within the PSZ fence. As this area is inaccessible and boreholes were drilled adjacent to this site during the Phase I RI, no additional boreholes are proposed. However, an additional borehole (BH2891) will be drilled in the possible eastern location of the Pallet Burn Site identified from historical aerial photographs. This borehole will aid in verifying the location of IHSS 154.

5 3 3 East Trenches Area

IHSSs within the East Trenches Area that will be investigated as part of this source characterization study include Trenches T-3 to T-11 and the two East Spray Fields

Trenches T-3 Through T-11 (IHSS Ref. Nos 110, 111 1 through 111 8)

As shown in Figure 1-5, IHSSs within the East Trenches are closely spaced and portions of the trenches are occupied by barrels. Location of boreholes and monitoring wells are presented in Plate 1 and summarized on Table 5-2

The boreholes proposed within the East Trenches are located in portions of the trenches devoid of barrels. Boreholes within the trenches will not only provide waste and source characterization, but also details on the construction of the trenches. Alluvial monitoring wells will be completed adjacent to all of the boreholes. These sampling locations are discussed below.

Five boreholes will be drilled through the northern trenches in areas not containing barrels. Borehole BH2991 will be drilled through the western end of Trench T-3 which is devoid of barrels, and boreholes BH3091 and BH3191 will be drilled through Trench T-4. Boreholes BH3291 and BH3391 will be drilled at the ends of Trench T-11 outside of the area containing barrels. Trench T-10 is filled with barrels, therefore, no boreholes will be drilled into this IHSS. Alluvial monitoring wells will be completed adjacent to all of the source characterization boreholes in the northern trenches (wells 88-91 through 92-91).

Nine boreholes (BH3491 through BH4191) will be drilled and sampled in portions of the southern trenches devoid of barrels (Table 5-2). All of these boreholes will have alluvial monitoring wells (93-91 through 100-91) completed adjacent to them to characterize alluvial ground-water quality immediately beneath the sites.

East Spray Field (IHSS Ref. Nos 216 2 and 216 3)

Four boreholes, BH4291 through BH4591, are proposed within the boundaries of the East Spray Field to characterize soils. Alluvial monitoring wells (wells 101-91 through 104-91) will be completed adjacent to all of the source characterization boreholes.

5 4 SURFICIAL SOILS SAMPLING PROGRAM

The contamination of surficial soils around Rocky Flats Plant by plutonium (Pu) oxides was mainly caused by leaking barrels of plutonium-contaminated oil in the area known as the 903 Pad (Krey and Hardy, 1970).

Numerous studies (Krey and Hardy, 1970, Seed, et al, 1971, Poet and Martell, 1972, Johnson, et al, 1976, Little, 1980, Little, et al, 1980) concluded that surficial soils in the area east of the 903 Pad are contaminated with plutonium and americium (Am) due to wind dispersal of soil particles during cleanup operations. More recently, the Phase I RI of the OU No 2 (Rockwell International, 1987a) found that the concentrations of plutonium and americium were elevated in composite soil samples adjacent to Trench T-2 (BH25-87, BH26-87, and BH27-87) and the Reactive Metal Destruction Site (BH28-87) T-1 (boreholes BH35-87 and BH36-87). In addition, the Phase I RI found occasional elevated concentrations of plutonium ($> 0.05 \text{ pCi/l}$) in filtered and unfiltered surface water samples from seeps (SW-50, SW-53, and SW-54) and in stream sediments ($> 0.9 \text{ pCi/g}$) along Woman Creek (SED-25, SED-26, SED-29, and SED-30). It has been suggested that the source of the contaminated sediments is the surface soils from the 903 Pad Area which are transported by wind. However, the elevated concentrations of plutonium in filtered and unfiltered seep waters above Woman Creek suggest that some of the plutonium may travel in surface and ground water. Also, soil sampling results indicate that the actinides are enriched near the ground surface. Further investigation is necessary to characterize the transport mechanisms that control the spatial and vertical distribution of these radionuclides.

The objectives of the proposed work plan for the surficial soils are to determine the spatial and vertical extent of plutonium and americium in soils of the remedial investigation areas, and in the buffer zone, to study the physicochemical association of plutonium and americium in surficial soils (static and mobile soil phases) above seeps SW-50, SW-53, and SW-54, to study the movement of both water and radionuclides (colloidal and dissolved) down the soil column, and, to ascertain the hydrogeochemical relationships between the soil interstitial water and the seeps downslope. A detailed sampling plan for surficial soils is provided in Attachment 10.

5.4.1 Spatial Distribution - Sampling

In order to assess the extent of plutonium and americium in surficial soils within the plant boundaries, soil samples will be collected across the area identified in Figure 5-2 consisting of approximately 800 acres. Figure 5-2 was constructed based on review of previous investigation results, data analysis of unpublished material, and radiological surveys. The geostatistical analysis of previous investigation results are presented in the surficial soil sampling plan (Attachment 10). The State of Colorado requires special techniques for construction on lands with plutonium concentrations greater than 0.9 pCi/g of dry soil. To evaluate the soil-plutonium values relative to this guideline, the CDH sampling protocol will be used.

The CDH sampling protocol requires 25 subsamples to be composited within a 10-acre area for plutonium and americium analysis. Because of the large variations in soil-plutonium near the source area, a 2.5-acre grid will be sampled immediately east of the 903 Pad and around the East Trenches Area (Figure 5-2). This sampling design will serve two purposes: (1) to increase the confidence in soil-plutonium estimates around the 903 Pad and East Trenches Areas, and, (2) to expand the number of soil data for kriging estimates. The soil sampling in the 2.5-acre areas will consist of 25 subsamples for plutonium, americium, and uranium determination. The soil sampling in the 10-acre grid areas will also consist of 25 subsamples for plutonium and americium determination. The northwest corner of each grid will be surveyed and identified with an appropriately marked steel post. Grids will be oriented on the cardinal compass directions. The 25 subsamples for each composite sample will be located with a hand held compass and tape measure using the northwest corner as the starting point. Additional 10-acre plots will be added if large concentrations of plutonium and americium are detected north of the Mound Area.

5.4.2 Vertical Distribution - Sampling

Twenty-three soil profiles will be excavated, described, and sampled in order to assess the vertical distribution of plutonium-239,240 and americium-241 in soils east of the Rocky Flats Plant. Ten soil profiles will be excavated in the immediate vicinity of the 903 Pad, East Trenches, and seep SW-53, and an additional 12 soil profiles will be excavated according to soil types, direction, and distance from the 903 Pad. The approximate locations for the proposed soil profiles are depicted in Figure 5-2. The soil profiles will be dug in undisturbed or the least disturbed sites which are characterized by the natural short grass prairie, pasture, and valley side vegetation (Clark, et al., 1980). The exact location of the soil profiles will be determined in the field using aerial photographs, soil and topographic maps, radiological surveys, and common sense. Transport of soil-plutonium in the soil environment is highly affected by soil type, moisture content, texture, structure, and particle characteristics such as shape, density, and cohesiveness (Burley, 1990). Hence, all the major soil types east of the 903 Pad (Table 2-2) will be sampled.

Surficial soil samples from the 23 soil profiles will be collected using a modified trench method (Harley, 1972). This method involves digging a trench with a backhoe or shovel 1.5 m long, 1.0 m wide and 1.0 m deep. One wall of the trench will be dug as a block/stair case (15 cm height each) to minimize cross contamination. The vegetation at the surface of the selected wall will be cropped closely to the surface and discarded. The soil morphology will be described according to the standard operating procedures for logging alluvial and bedrock material (SOP 3.1, EG&G 1990). The soil will be sampled at intervals of 3 cm starting at the deepest block/stair in a given pit. Soil samples will be collected using a stainless steel scoop and template (3 cm x 20 cm) which will be pressed into the wall of the block/stair case. Three samples from each depth will be consolidated to provide a better representation of the site and to produce enough soil material for the various chemical analyses described in the following sections. After a sample has been collected, the soil layers below

it will be cleared of sloughed material to prevent possible contamination from the upper soil layers. A flag will be placed on the ground surface of a given pit and the depth below surface for each sample will be measured from the base of the flag. Each pit will be backfilled with the original soil mixture removed during the excavation.

5 4 3 Static Phase Physicochemical Association of Plutonium and Americium

The physicochemical association of plutonium and americium in the soils east of the 903 Pad will be studied using a sequential extraction methodology. The soils will be extracted into four major physicochemical fractions - carbonates, organics, sesquioxides, and residues. This partitioning is described below (Static Soil Phase - Proposed Work) and Attachment 1 0. Transport mechanisms of actinides in the soil profile will also be evaluated (mobile soil phase). Methods used to determine these leaching mechanisms include the collection of soil interstitial water and surface runoff water, recording precipitation events, and hydrologic rain model simulation. These methods are described in Section 5 4 4 and in Attachment 1 0.

5 4 3 1 Static Soil Phase - Proposed Work

Plutonium determination in the static soil phase will be performed on four sequential selective extracts in triplicates to assess the physicochemical association of plutonium. This is accomplished by partitioning each pedologic sample into the four fractions described below: calcium carbonate (CaCO_3), organic carbon (C), sesquioxides, and residue (Figure 1-9 of Attachment 1 0). In this study of the static soil phase, the gamma emitting isotope, plutonium-237 will be used as a tracer to assess the degree of post-extraction readsorption of plutonium isotopes (plutonium-239,240) during the various extractions performed on the soils. In addition, the sequence of extractions, shown in Figure 1-9 of Attachment 1 0, will be modified to test the uniqueness of an individual extraction.

5 4 3 2 Partitioning of Soil Fractions

Fraction 1 Carbonates In the soil environment, carbonates are susceptible to changes in pH which will induce the release of adsorbed plutonium. Carbonates will be removed by 0.5 molar (M) sodium acetate-acetic acid buffer solution ($\text{NaC}_2\text{H}_3\text{O}_2 \cdot \text{H}_2\text{O}$), adjusted to pH 5. This buffer treatment removes metals held in carbonates (coprecipitate with carbonates and/or adsorbed by iron and manganese oxides which have precipitated onto the carbonates) (Jenne, 1977). This buffer apparently does not attack the resistant sesquioxide phases to any great extent and leaves the lattice structure of silicate minerals intact (Chao, 1984).

Fraction 2 Organic In natural conditions, organic carbon is gradually decomposed, which may lead to release of soluble and colloidal plutonium. The organic carbon will be extracted by NaOCl at pH 9.5.

Lavkulich and Wiens (1970) removed up to 98 percent of the oxidizable organic carbon from 16 soil samples by three successive extractions with sodium hypochlorite. The sodium hypochlorite treatment is the preferable solution for extracting plutonium from soil organic matter because it does not appear to dissolve sesquioxide phases. It should be noted, however, that sodium hypochlorite will attack sulfides that may be present in the sample.

Fraction 3 Sesquioxides Sesquioxides are excellent scavengers of trace metals and are extremely unstable under anoxic conditions. There are various techniques to extract iron, manganese, and aluminum oxides in soils. These methods were developed to selectively dissolve the various mineralogical forms and degree of fineness of the sesquioxides present in soils. In the context of the proposed study, the citrate-bicarbonate-dithionite buffer method (Jackson, et al., 1986) is superior to other methods because it dissolves amorphous sesquioxides completely whereas the highly crystalline sesquioxides (e.g., hematite and goethite) will be partially dissolved. The degree of dissolution of the highly crystalline sesquioxides is dependent on the crystallinity and the fineness of grinding of the oxides. Hence, in order to obtain complete dissolution of crystalline sesquioxides, the soil samples will be finely ground and three multiple extractions will be performed.

Fraction 4 Residue After removal of the above chemical phases from the soil sample, the residue consists of silicates and some other resistant mineral species such as ilmenite and magnetite. The residue will be dissolved by strong digestion with hydrofluoric acid (HF) in conjunction with perchloric acid (HClO₄).

Experimental Conditions

- (a) **Bound to Carbonates** The soils will be extracted for 5 hours with 20 mL of 1M sodium acetate-acidic acid solution adjusted to pH 5.0. Detailed description of this extraction is given by Nelson (1982).
- (b) **Bound to Organics** The residue from (a) will be extracted for 5 hours with 20 mL of 1M sodium hypochlorite solution adjusted to pH 9.5. Detailed description of this extraction is given by Hoffman and Fletcher (1981).
- (c) **Bound to Sesquioxides** The residue from (b) will be extracted for 6 hours with 100 mL of 0.3M sodium citrate mixed with 1M sodium carbonate solution and appropriate amounts of sodium dithionite and sodium chloride salts. This extract will be repeated three times to assure almost complete dissolution of highly crystalline iron oxides. Detailed description of the extraction is given by Jackson, et al. (1986).

- (d) **Residual** The residue from (c) will be digested by a 5:1 mixture of hydrofluoric and perchloric acids. For a 1-g (dry weight) sample, the soil will be first digested in a platinum crucible with a solution of concentrated HClO_4 (2mℓ) and HF (10mℓ) to near dryness. Subsequently, a second addition of HClO_4 (1mℓ) and HF (10mℓ) will be made, and again the mixture will be brought to near dryness. Finally, HClO_4 (1mℓ) will be added and the sample will be evaporated until the appearance of white fumes. Further details of this extraction is given by Lim and Jackson (1982).

After each extraction the sample will be centrifuged at 10,000 revolutions per minute (rpm) for 30 minutes. The supernatant will be removed with a pipet and prepared for plutonium analysis. The residue will be washed with 10 mℓ of deionized water to remove residual salt from the previous extraction. The volume of the rinse water will be kept at a minimum to avoid excessive solubilization of organic matter.

5.4.3.3 Tracer Study

Spikes of plutonium-237 will be added to soil samples (triplicates) before each extract step (Figure 1-9, Attachment 1.0). The percentage of spike recovery and possible readsorption of the tracer will be carefully determined. In case of serious postextraction readsorption (> 15 percent) the selective sequential extraction will not be performed. In case the selective sequential extraction procedure is rejected, samples collected from pits X1 to X5 will only be analyzed for total plutonium-239, and 240 and americium-241.

5.4.4 Mobile Soil Phase - Physicochemical Association of Plutonium and Americium

The mobility and the environmental fate of actinides in soils are usually studied by extracting the soil matter. In general, these analyses fail to provide important information regarding the transport mechanisms of pollutants within the soil column. Hydrological analysis of the frequency, duration and intensity of summer precipitation events and spring snowmelt events, coupled with direct measurements of solute transport in soils will provide essential information to assess the form and magnitude of actinide movement in soil.

5.4.4.1 Objectives and Hypotheses

The objectives of the proposed mobile soil phase work are to

- Estimate the importance of vertical flow in the soil environment upslope from seep SW-53 during and after major precipitation events.
- Assess the relationships between soil-plutonium in the interstitial waters and plutonium in the seep SW-53.

The proposed design is based on three hypotheses

- Leaching episodes in the soils will transport solute and colloidally-bound actinides down the soil column
- Freely flowing waters in the soil environment will carry different actinide concentrations than soil solutions collected at higher matrix potentials
- The occasional elevated concentrations of plutonium in seep SW-53 were originated by vertical leaching of plutonium from the soil environment upslope

5 4 4 2 Mobile Phase - Proposed Work

Testing these hypotheses will require in situ sampling of soil interstitial waters over time. More specifically, it will be necessary to develop a fully-automated, remote-controlled soil solution sampling system that is capable of (a) collecting freely flowing water [0 to 5 kiloPascals (kPa) matrix potential] mainly via macropores, (b) collecting soil solutions flowing in micropores at higher matrix potential (5 to 40 kPa), and (c) provide accurate and timely measurements of incoming precipitation. This apparatus will consist of five major modules

- An automated zero-tension sampler in which freely flowing water, mainly in macropores (formed by frost heave cycles and swelling and shrinking of clays), will be accurately collected for assessing the subsurface flow during and after major precipitation events
- A fluxmeter which will provide the unsaturated flux as the soil dries out as well as soil solutions for radiochemistry analyses
- Tipping bucket rain gauge
- Time domain reflectometry (TDR) soil moisture probes which will measure in situ soil water content
- Telemetry communication which will send the data collected in the field to a base station at T130B (Figure 1-10, Attachment 1 0)

The vertical water flow data obtained in situ will be used to test the infiltration rates and flow estimates calculated by the unsaturated flow model, being developed by CSU (mid-1991), for the area east of the 903 Pad. The chemical characterization study will include (1) total concentrations of plutonium and americium in soil interstitial waters that move freely (0 to 5 kPa) down the soil column and (2) fractionation of actinides in colloidal and dissolved [< 0.1 micrometer (μm)] phases in freely flowing waters (0 to 5 kPa) and various matrix potentials (5 - 10, 10 to 30, and 30 to 50 kPa).

The chemical characterization will be performed using zero-tension samplers and fluxmeters. The zero-tension sampler will be made of 40 cm segments of plexiglass (25 cm width) with one end plugged with a plexiglass

stopper containing a collecting tube and the other end sharpened. The sharpened end will be driven into the western pit face with a mallet to a depth of 40 cm to ensure minimal structure and textural disturbance to the soil. The water sampled by the zero-tension sampler will be collected by a 2 liter (ℓ) bottle mounted on a load cell. The temperature of the soil interstitial waters and the soil matrix will be measured by a temperature probe. The temperature and amount of water in the collection bottle will be simultaneously transmitted to a data logger.

The transmitted information will be transferred daily to the base station via telemetry. Sending the data via telemetry to the base station (T130B) will provide crucial information regarding the time and frequency of field sampling.

The soil test pits will be refilled after access tubes are inserted to prevent convergence flow and to minimize further disturbance. The zero-tension soil solution samplers will be installed upslope of seep SW-53 every 10 to 15 cm down the soil column to the depth of the caliche horizon or other semi-impermeable layer in the five soil profiles (site X1 through X5, Figure 5-2).

The fluxmeter consists of three components: a Teflon cylinder soil water sampler which is treated with silica to reduce hydrophobicity, three TDR soil moisture probes, and a portable vacuum pump with a buffer container. Each Teflon sampler will be installed with three TDR soil moisture probes around it and connected, via Teflon tubing, to a 2 ℓ collecting bottle equipped with a special screw cap of polyethylene with a teflon gasket and fittings. The 2 ℓ collecting bottle will be residing inside a thermo-box which will minimize temperature fluctuations in the field. Two types of Teflon cylinder soil water samplers will be used: a teflon cylinder with an average pore size of 10 μm for sampling large water volumes during short flow episodes, and a teflon cylinder with an average pore size of 5 μm for normal operational conditions. Ten Teflon cylinder soil water samplers will be installed at five different depths in each pit (X1 through X5 of Figure 5-2) excavated for the zero-tension sampler. The Teflon cylinder soil water samplers will be installed into the face of the soil pit using a stainless-steel rod. The soil moisture probes will be connected via coaxial cable to a Tektronix cable tester, equipped with a communication interface, to a datalogger (Figure 1-11 of Attachment 10). Once the soil moisture of the soil exceeds a pre-set value the vacuum pump will be activated to produce an equivalent vacuum inside the tension sampler. The equivalent vacuum will be derived from the linear relationships between soil moisture and matrix potential values in the range of 0.1 to 50 kPa.

The soil interstitial waters collected by the zero-tension samplers and the tension samplers will be filtered on the day of sampling using 0.45 and 0.1 μm Millipore filters. The total colloidal bound plutonium will be determined from the material that was retained on the filters. The dissolved plutonium will be determined from the water that passed through the filter.

The frequency, duration and intensity of summer precipitation will be determined by a tipping bucket rain gauge. This rain gauge is an integral part of the proposed apparatus and will be mounted in the middle of the transect. The rain gauge will simultaneously transfer the data to the data logger which will transmit this information via telemetry to the base station in T130B. The amount and nature of precipitation and soil water flux will be recorded and checked daily. The frequency of field sampling will be determined on the basis of the transmitted data. This data will be used to prepare a precipitation model for hydrologic simulation and analysis.

The amount of water that can be collected by this apparatus in Rocky Flats Plant soils is currently unknown. One to two liters of interstitial waters were collected every week during snowmelt and after every major precipitation event in forested and alpine ecosystems using a simplified version of the proposed apparatus (Litaor, 1988). Hence, two rain simulation experiments will be conducted before the beginning of the precipitation season. The first experiment will be used to verify that all the components of the apparatus are interfacing and communicating with each other and the base station. Calibration of the load cells and the TDR soil moisture probes will be performed during the first rain simulation experiment. The magnitude and duration of the second simulated rain will be determined by reviewing precipitation data collected at Rocky Flats Plant in the last five years to determine the magnitude and frequency of the storm events. Soil solution collected during the second simulation experiment will be submitted for radionuclides analyses.

5 4 4 3 Rain Simulation

The importance of hydrologic model simulation of rain and snow precipitation in the proposed work can be summarized as follows: (1) rain simulation yields more rapid results, especially in the testing of the extreme conditions (e.g., rainfall in arid and semi-arid conditions), and, (2) rain simulation is more controlled inasmuch as one can take appropriate measurements with selected intensities and durations. The rain simulator described by Ghodrati, et al. (1990) will be used in the proposed work. This rain simulator can employ spatially uniform application of water to small plots (1 to 2 m²). The simulated rainwater will have the same ionic strength as the average rainwater observed at Rocky Flats Plant.

5 5 FIELD AND ANALYTICAL LABORATORY PROGRAMS

Field testing will include headspace tests for organics, gross alpha and beta radiological tests, geologic logging, photography, and hydrologic tests. All of the above are field screening and data logging activities described in the SOPs. The hydrologic testing will be conducted as proposed below. All of these data will be incorporated into the EG&G Rocky Flats data base.

5 5 1 Hydraulic Testing Program

Three multi-well pumping and tracer tests will be performed to evaluate the hydraulic properties of the subsurface materials at the 903 Pad, Mound, and East Trenches Areas. The goals of the program are to

- Develop parameters for rate of movement calculations (hydraulic conductivity and effective porosity) for both the bedrock and alluvial materials
- Evaluate the degree of connection between the alluvium and the bedrock (both sandstone and claystone)
- Develop parameters for estimation of production rates from remedial ground-water collection systems

The testing program has been designed based on the hydrogeologic model of the subsurface described in earlier sections of this plan. Three distinct hydrogeologic situations are present in the upper HSU at the 903 Pad, Mound, and East Trenches Areas

- 1) The Rocky Flats Alluvium is unsaturated and is directly underlain by the of the Arapahoe Number One Sandstone Formation (saturated)
- 2) The Rocky Flats Alluvium is directly underlain by the Number One Sandstone and both are saturated
- 3) The Rocky Flats Alluvium is saturated and is underlain by claystone of the Arapahoe Formation

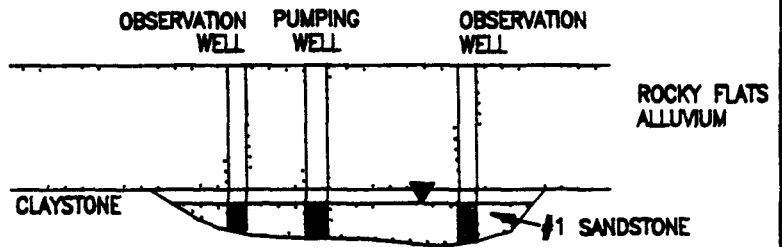
Hydrologic pumping tests have been designed to evaluate hydraulic conductivity, storage properties, and the effective porosity for each of these situations. Schematics of the subsurface conditions and test well layouts are shown on Figure 5-3

Detailed designs for each of the hydrologic pumping tests are presented below, however, before the tests are actually performed, the production wells will be installed and tested (step-drawdown or other single hole technique) to establish better estimates of the hydraulic properties at the test locations. The hydrologic tests will then be re-evaluated and possibly re-designed (observation well locations, pumping rates and duration of pumping). After re-evaluation of the test designs, the observation wells will be installed and the hydrologic tests will be performed. All water produced during the hydrologic pumping testing of the production wells will be stored in tanker trucks and reinjected into the production well from which the water was produced.

TEST T-1

ALLUVIUM DRY
SATURATED SANDSTONE

MULTI-WELL PUMPING TEST
CONVERGING RADIAL TRACER TEST

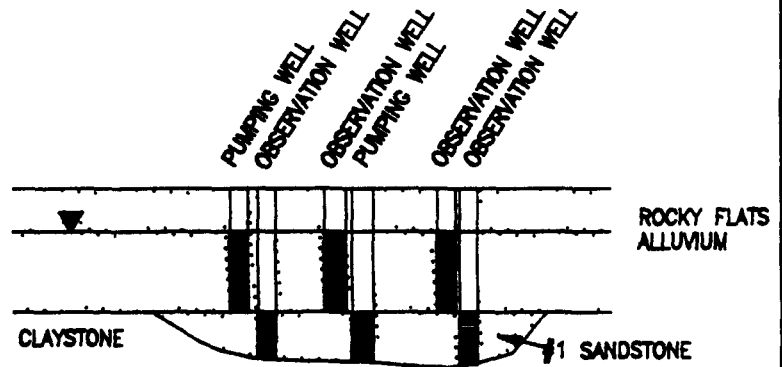


TEST T-2

SATURATED ALLUVIUM &
SATURATED SANDSTONE

PUMPING TEST OF ALLUVIUM WITH
OBSERVATION WELLS IN SANDSTONE

PUMPING TEST OF SANDSTONE WITH
OBSERVATION WELLS IN ALLUVIUM

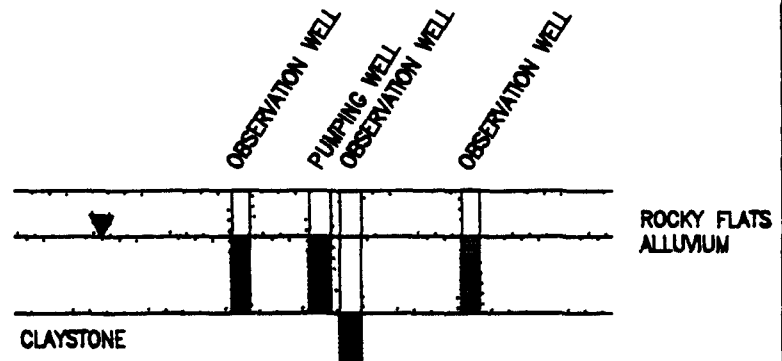


TEST T-3

SATURATED ALLUVIUM
UNDERLAIN BY CLAYSTONE

PUMPING TEST OF ALLUVIUM WITH
OBSERVATION WELL IN CLAYSTONE

CONVERGING RADIAL TRACER TEST



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OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

HYDRAULIC TEST DIAGRAMS

FIGURE 5-3

February, 1991

5 5 1 1 Case 1 Unsaturated Alluvium over Saturated Sandstone

A multi-well pumping test followed by a converging radial tracer test will be performed at the T-1 location shown on Plate 1. An array of one production well and four observation wells will be completed in the Number One Sandstone. The observation wells will be located at distances of 5, 10, 20 and 40 feet from the production well (Figure 5-4).

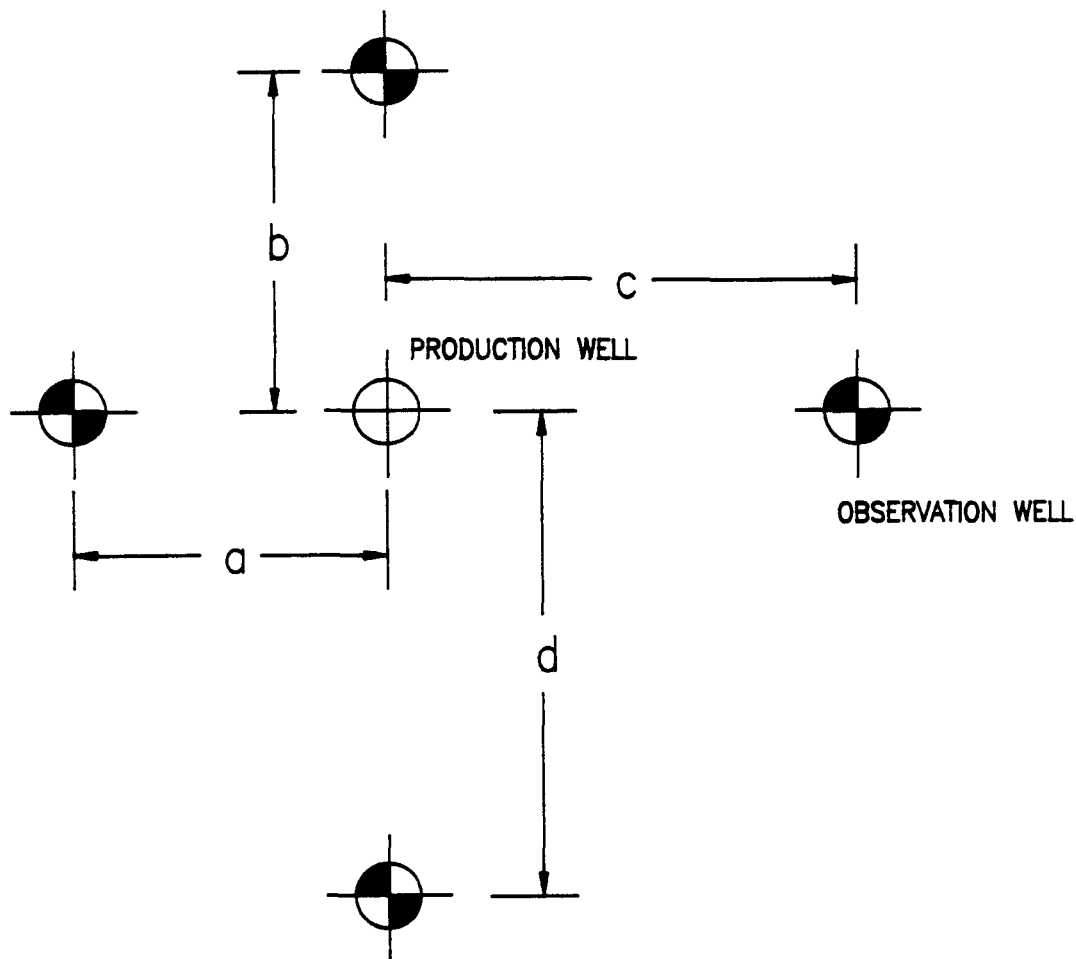
Initial pump rates will be determined by using Theis (1935) and hydraulic properties developed in the Phase I RI (hydraulic conductivity of 4×10^{-4} cm/s, storage coefficient of 0.1 and saturated thickness of 15 feet). A steady pumping rate of one gpm is estimated for wells at the T-1 location. If the test array is located approximately 40 feet from the edge of the sandstone channel, significant interference from the boundary (additive drawdown of 0.5 feet) should be observable in the most distant observation well after five days of pumping. All produced water (7,200 gallons) will be stored in tanker trucks and then reinjected into the production well at the end of the recovery period (see below).

Immediately following the five days of steady pumping, a converging radial tracer test will be performed by injecting rhodamine-WT dye into the observation well located five feet from the production well (steady pumping will continue throughout the tracer test). It is anticipated that the 50 percent concentration (C_{50}) will arrive at the production well approximately ten hours after introduction of the fluorescent dye. The entire pump test will require approximately 24 hours to complete. The tracer test results will be analyzed using methods described by Sauty (1980).

After completion of the tracer test, recovery of the system will be monitored for an additional six days. Drawdowns in the observation and production wells will be evaluated using methods described in Bedinger and Reed (1988), such as Neuman (1972 and 1973).

5 5 1 2 Case 2 Saturated Alluvium over Saturated Sandstone

Two multi-well pumping tests will be performed at the T-2 location shown on Plate 1. An array of one production well and four observation wells will be completed in the Rocky Flats Alluvium, and a second array of one production well and four observation wells will be completed in the Number One Sandstone. The observation wells in the Rocky Flats Alluvium will be located at distances of 5, 10, 30 and 75 feet from the production well. The observation wells in the Number One Sandstone will be located at distances of 5, 10, 20 and 40 feet from the production well (Figure 5-4).



EXPLANATION OF WELL SPACINGS (FEET)

	a	b	c	d
Sandstone	5	10	20	40
Alluvium	5	10	30	75

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

OBSERVATION WELL LAYOUT

FIGURE 5-4

February, 1991

R33075 PJ-020491

A five day production test of the Rocky Flats Alluvium will be performed with an additional five days of recovery. Water level responses will be measured in wells that monitor in both the alluvium and the sandstone. A second five day production test of the sandstone will be performed with monitoring of observation wells in both the alluvium and the sandstone. The test period will be designed based on previous pump test data. A tracer test will not be performed as part of this test because of expected interference (dilution effects) from the overlying or underlying units.

The pumping test of the sandstone will be conducted at one gpm (see discussion of Case 1 above for expected production volume and aquifer responses). An estimated steady pumping rate of three gpm flow from the alluvium has been calculated using the Theis Method (1935), and alluvial hydraulic properties developed in the Phase I RI (hydraulic conductivity of 1×10^{-2} cm/s, storage coefficient of 0.1 and saturated thickness of five feet). At the end of the recovery period for the second test, all produced water (22,000 gallons from the alluvium and 7,200 gallons from the sandstone stored in separate tanker trucks) will be reinjected into the production well from which the water came.

Drawdowns in the observation and production wells will be evaluated using numerical modeling techniques, such as Lappala, et al (1987), as well as the more standard methods described in Bedinger and Reed (1988). However, because the hydrogeologic conditions do not meet the assumptions of the standard leaky-aquifer analyses, it is anticipated that numerical modeling will be the effective method to evaluate the interconnection between the alluvium and the sandstone.

5.5.1.3 Case 3 Saturated Alluvium over Claystone

A multi-well pumping test followed by a converging radial tracer test will be performed at the T-3 location shown on Plate 1. An array of one production well and four observation wells will be completed in alluvium. The observation wells will be located at distances of 5, 10, 30 and 75 feet from the production well (Figure 5-4). In addition, a single observation well will be installed adjacent to the production well to monitor head response at a depth of approximately five feet into the claystone.

An estimated steady pumping rate of three gpm flow from the alluvium has been calculated using the Theis Method (1935), and alluvial properties developed in the Phase I RI (hydraulic conductivity of 1×10^{-2} cm/s, storage coefficient of 0.1 and saturated thickness of five feet). All produced water (22,000 gallons) will be stored in tanker trucks and reinjected into the production well at the end of the recovery period. Using a simple finite-difference evaluation, it is estimated that a water level response will be measurable in the claystone (0.1 feet of drawdown for a vertical conductivity of 1×10^{-6} cm/s) after five days of pumping.

Immediately following the five days of steady pumping, a converging radial tracer test will be performed by injecting rhodamine-WT dye into the observation well located five feet from the production well. It is anticipated that the 50 percent concentration will arrive at the production well approximately one hour after the introduction of the fluorescent dye, and that the entire test will require approximately 24 hours to complete. The tracer test will be analyzed using methods described by Sauty (1980).

After completion of the tracer test, recovery of the system will be monitored for an additional six days. Drawdowns in the observation and production wells in the alluvium will be evaluated using methods described in Bedinger and Reed (1988). The response of the observation well in the claystone will be evaluated using methods described in Bedinger and Reed (1988), such as Lappala, et al (1987).

5.5.2 Ground-water Sampling Program

Ground-water samples will be collected on a quarterly basis from all new and existing monitoring wells at the 903 Pad, Mound, and East Trenches Areas upon completion of well development. Samples will be analyzed for the parameters listed in Table 5-3 during the first round of sampling after completion of new wells. This parameter list may be reduced in subsequent quarterly sampling events if certain parameter groups are not detected, or are not significantly above background levels and if approved by EPA and CDH. Ground-water samples will be analyzed in the field for pH, conductivity, temperature, and dissolved oxygen. Sample aliquots designated for metals and radionuclide analyses will be filtered with the exception of tritium. All sample filtration and preservation will be performed in the field.

5.5.3 Borehole Sampling Program

Borehole samples will be collected from boreholes within and adjacent to IHSSs to characterize both plumes and sources. All borehole samples will be analyzed for the chemical parameters listed in Table 5-3 following CLP methods or the methods provided in the GRRASP (EG&G, 1990k) plan. These parameters are essentially the same as those analyzed in the Phase I RI except that oil and grease and RCRA characteristics are eliminated. Oil and grease have not proven useful in determining extent of soil contamination, and RCRA hazardous waste characteristics have been within acceptable limits. The TCL list for organics and the TAL list for inorganics are nearly the same as the previously used HSL list for organics and inorganics. The physical properties of on-site geologic materials will also be characterized to support the evaluation of remedial action alternatives. Bulk samples will be collected from continuous core of alluvial wells to characterize each of the materials found within the 903 Pad, Mound and East Trenches Areas (Rocky Flats Alluvium, colluvium, valley fill alluvium, and weathered bedrock). Specifically, ten samples of each geologic material type will be submitted for grain size analyses (sieve and hydrometer analyses), Atterberg limits testing, and recompacted permeability testing to evaluate the variability of these parameters across the site.

TABLE 5-3

**PHASE II RFI/RI
SEDIMENT, BOREHOLE, SURFACE WATER, AND GROUND-WATER
SAMPLING PARAMETERS**

TOTAL METALS

Target Analyte List -
Sediment and Boreholes

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Vanadium
Zinc

OTHER METALS

Sediment and Boreholes
Molybdenum
Strontium
Cesium
Lithium
Tin

OTHER INORGANICS

Sediment and Boreholes
pH
Sulfide
Nitrate-Nitrite (as N)
Percent Solids
Cyanide
Moisture Content
Orthophosphate
Bromide
Ammonium
Silica (as Si and SiO₂)

INDICATORS

Sediment and Boreholes
Dissolved Organic Carbon
Total Organic Carbon

OTHER PARAMETERS

Total Petroleum Hydrocarbons*

METALS

Target Analyte List -
Ground Water (Dissolved Metals)
and Surface Water (Total and Dissolved Metals)

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Vanadium
Zinc

OTHER METALS

Ground Water and Surface Water
Molybdenum
Strontium
Cesium
Lithium
Tin

FIELD PARAMETERS

Ground Water and Surface Water
pH
Specific Conductance
Temperature
Dissolved Oxygen

INDICATORS

Ground Water and Surface Water
Total Dissolved Solids
Total Organic Carbon
Dissolved Organic Carbon
pH

INDICATORS

Surface Water
Total Suspended Solids

ANIONS

Ground Water and Surface Water
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate as N
Cyanide
Fluoride
Bromide
Silica (as Si and SiO₂)
Ammonium
Orthophosphate

TABLE 5-3 (Continued)

PHASE II RFI/RI
SEDIMENT, BOREHOLE, SURFACE WATER, AND GROUND-WATER
SAMPLING PARAMETERS

OTHER PARAMETERS

Ground Water
Total Petroleum Hydrocarbons*

DISSOLVED RADIONUCLIDES**

Ground Water and Surface Water
Gross Alpha
Gross Beta
Uranium -233&234,235, and 238
Americium -241 (surface water only)
Plutonium -239&240 (surface water only)
Tritium
Strontium -89,90
Cesium 137
Radium 226,228***
Tritium

TOTAL RADIONUCLIDES

Sediment and Boreholes
Gross Alpha
Gross Beta
Uranium -233&234,235, and 238
Americium -241
Plutonium -239&240
Tritium
Strontium -89,90
Cesium -137
Radium -226, 288

TOTAL RADIONUCLIDES

Surface Water
Uranium -233&234,235, and 238
Plutonium -239&240
Americium -241
Cesium -137
Strontium -89,90
Radium -226,228**
Tritium

Ground Water
Plutonium -239&240
Americium -241
Tritium

ORGANICS. VOLATILES

Target Compound List -
Sediment and Boreholes
Chloromethane
Bromomethane
Vinyl Chloride
Chloroethane
Methylene Chloride
Acetone
Carbon Disulfide
1,1-Dichloroethene
1,1-Dichloroethane
total 1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon Tetrachloride
Vinyl Acetate
Bromodichloromethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
cis-1,3-Dichloropropene
Bromoform
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene
Toluene
Chlorobenzene

ORGANICS: VOLATILES

Target Compound List -
Ground Water and Surface Water
Chloromethane
Bromomethane
Vinyl Chloride
Chloroethane
Methylene Chloride
Acetone
Carbon Disulfide
1,1-Dichloroethene
1,1-Dichloroethane
total 1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon Tetrachloride
Vinyl Acetate
Bromodichloromethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
cis-1,3-Dichloropropene
Bromoform
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene
Toluene
Chlorobenzene

TABLE 5-3 (Continued)

PHASE II RFI/RI
SEDIMENT, BOREHOLE, SURFACE WATER, AND GROUND-WATER
SAMPLING PARAMETERS

ORGANICS. VOLATILES (continued)

Target Compound List -
Sediment and Boreholes
Ethyl Benzene
Styrene
Total Xylenes

ORGANICS: VOLATILES (continued)

Target Compound List -
Ground Water and Surface Water
Ethyl Benzene
Styrene
Total Xylenes

ORGANICS: SEMI-VOLATILES

Target Compound List -
Sediment and Borehole
Phenol
bis(2-Chloroethyl)ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl Alcohol
1,2-Dichlorobenzene
2-Methylphenol
bis(2-Chloroisopropyl)ether
4-Methylphenol
N-Nitroso-Dipropylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Benzoic Acid
bis(2-Chloroethoxy)methane
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-methylphenol (para-chloro-
meta-cresol)
2-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethylphthalate
Acenaphthylene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diethylphthalate
4-Chlorophenyl Phenyl ether
Fluorene
4-Nitroaniline
4,6-Dinitro-2-methylphenol
N-nitrosodiphenylamine
4-Bromophenyl Phenyl ether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butylphthalate
Fluoranthene
Pyrene
Butyl Benzylphthalate
3,3'-Dichlorobenzidine
Benzo(a)anthracene
bis(2-ethylhexyl)phthalate

ORGANICS: SEMI-VOLATILES

Target Compound List -
Ground Water and Surface Water****
Phenol
bis(2-Chloroethyl)ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl Alcohol
1,2-Dichlorobenzene
2-Methylphenol
bis(2-Chloroisopropyl)ether
4-Methylphenol
N-Nitroso-Dipropylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Benzoic Acid
bis(2-Chloroethoxy)methane
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-methylphenol (para-chloro-meta-
cresol)
2-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethylphthalate
Acenaphthylene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diethylphthalate
4-Chlorophenyl Phenyl ether
Fluorene
4-Nitroaniline
4,6-Dinitro-2-methylphenol
N-nitrosodiphenylamine
4-Bromophenyl Phenyl ether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butylphthalate
Fluoranthene
Pyrene
Butyl Benzylphthalate
3,3'-Dichlorobenzidine
Benzo(a)anthracene
bis(2-ethylhexyl)phthalate

TABLE 5-3 (Continued)

PHASE II RFI/RI
SEDIMENT, BOREHOLE, SURFACE WATER, AND GROUND-WATER
SAMPLING PARAMETERS

ORGANICS SEMI-VOLATILES (continued)

Target Compound List -
Sediment and Borehole
Chrysene
Di-n-octyl Phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenz(a,h)anthracene
Benzo(g,h,i)perylene

ORGANICS: SEMI-VOLATILES (continued)

Target Compound List -
Ground Water and Surface Water****
Chrysene
Di-n-octyl Phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenz(a,h)anthracene
Benzo(g,h,i)perylene

ORGANICS: PESTICIDES/PCBs

Target Compound List -
Sediment and Boreholes
alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Heptachlor
Aldrin
Heptachlor Epoxide
Endosulfan I
Dieldrin
4,4'-DDE
Endrin
Endosulfan II
4,4'-DDD
Endosulfan Sulfate
4,4'-DDT
Endrin Ketone
Methoxychlor
alpha-Chlordane
gamma-Chlordane
Toxaphene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260

ORGANICS: PESTICIDES/PCBs

Target Compound List -
Ground Water and Surface Water****
alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Heptachlor
Aldrin
Heptachlor Epoxide
Endosulfan I
Dieldrin
4,4'-DDE
Endrin
Endosulfan II
4,4'-DDD
Endosulfan Sulfate
4,4'-DDT
Endrin Ketone
Methoxychlor
alpha-Chlordane
gamma-Chlordane
Toxaphene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260

SURFICIAL SOIL SAMPLE PARAMETERS

Total Organic Carbon
Organic Carbon Extraction*****
Carbonate
Carbonate Extraction*****
Sesquioxide Extraction*****
Residual Extraction*****

pH
Specific Conductance
Plutonium-239 & 240
Americium-241
Uranium-233 & 234, 235, and 238

- * For samples collected from IHSSs 102 and 105 only (69-91/BH0191, 70-91/BH0291, BH0391, 71-91/BH0491, 72-91/BH0591, 73-91/BH0691, BH0791, 74-91/BH0891, BH0991, BH1591, 79-91/BH1691, BH1791, BH1891)
- ** Samples for total radionuclides for groundwater will be collected if sufficient water can be evacuated from the well to fill the appropriate containers
- *** Decision tree If Gross Alpha is ≥ 5 pCi/l the sample will be analyzed for Radium-226,228
- **** Semi-volatiles and Pesticide/PCB samples are collected during the quarterly surface water sampling events
- ***** See Attachment 10, Section 1.5.3.2 for extraction methodologies
- NOTE The priority list for ground-water sample parameters for wells which yield insufficient water to obtain the entire analytical suite is provided in the ER Program SOPs

Sheet 4 of 4

5 5 4 Surficial Soils Analyses

Composite surficial soil samples collected from the 40 2 5 acre grids (Figure 5-2) will be analyzed for plutonium-239, 240, americium-241, and uranium-232, 233, 235, and 238. Samples obtained from the 82 sites selected within 10-acre grids will be analyzed for plutonium and americium. These analyses will be used to determine the spatial distribution of actinides in the surficial soils at Rocky Flats Plant east of the 903 Pad.

Soil samples from the 22 soil profiles will be analyzed for plutonium and americium to assess their vertical distribution in the soils. Soil organic carbon, soil pH, calcium carbonate content, and specific conductance will also be determined on samples from each of the soil profiles. All samples from the 22 profiles will be subjected to the carbonate and organic carbon extractions described in Section 5 1 3 3. In addition, samples from profiles X1 through X5 will also be subjected to sesquioxide and residue extractions.

In conjunction with the chemical analyses, soil physical measurements will also be conducted on samples from selected soil profiles. Specifically, particle size analysis and bulk density will be performed on a sample from one profile representative of each soil type (Table 2-2 and Figure 2-6).

5 5 5 Surface Water and Sediment Sampling Programs

Surface water and sediment samples are being collected from seeps and bodies of water within South Walnut and Woman Creek drainages as part of monthly site-wide water quality programs. The sample stations of most importance to OU No. 2 are shown in Table 5-4. This water quality data set is available for analyses as part of the OU No. 2 Phase III RFI/RI report and for the two work plans in alluvium and bedrock media.

5 5 5 1 Sample Locations

Nineteen surface water and seep water stations were established south of the 903 Pad and East Trenches Areas in the Woman Creek drainage during the 1986 and 1987 investigations, 12 stations were also established north of the Mound and East Trenches Areas in the South Walnut Creek drainage in 1988. These 31 existing stations are being sampled monthly during the site-wide routine sampling program with the exception of SW-21, SW-24, and SW-25, which have been eliminated as sampling stations. Four new sampling locations have been added. Station SW-132 is located approximately 225 feet downstream of SW-61, where flow from the upper reach of South Walnut Creek is discharged from the outlet of a corrugated metal culvert, and SW-133 is located at the concrete culvert discharge to the South Walnut Creek drainage just north of SW-60. Monthly samples are also being collected from Ponds C-1 and C-2. Figure 2-11 presents surface water monitoring locations in the area, and Table 5-4 lists the two surface water stations.

Sediment samples were taken in October 1989 at stations along South Walnut Creek as well as Woman Creek and the SID. The resulting data should suffice as confirmatory information regarding the concentrations of volatile organics, metals, other inorganics, and radionuclides in the sediments. For the Phase II RFI/RI, physical characteristics of the sediments (background and "downgradient") and the spatial distribution of the metal concentrations will be examined to assess the adequacy of the background sediment geochemical characterization, and thus whether metals are contaminants in the sediments at the 903 Pad, Mound, and East Trenches Areas.

5.5.5.2 Chemical Analyses of Surface Water and Sediment Samples

Surface water and sediment sampling is being conducted as part of the site-wide routine sampling program. Surface water samples are being analyzed in the field for pH, conductivity, temperature, and dissolved oxygen. Laboratory analyses of surface water and sediment samples consists of the parameters listed in Table 5-3. All samples requiring filtration are filtered in the field, and all samples are preserved in the field. Surface water sampling and stream flow measurements follow the procedures described in the Rocky Flats ER Program SOP.

5.6 DATA MANAGEMENT

Field and laboratory data collected during the Phase II RFI/RI will be incorporated into the Rocky Flats Environmental Database System (RFEDS). The RFEDS is used to track, store, and retrieve project data. Data will be input to the RFEDS via diskettes subsequent to data validation as outlined in the ER Program QAPJP (EG&G, 1990). Hardcopy reports will then be generated from the system for data interpretation and evaluation.

TABLE 5-4

SURFACE WATER SAMPLING STATIONS

<u>Station Number</u>	<u>Seep</u>	<u>Stream</u>	<u>Pond</u>	<u>Ditch</u>	<u>Other</u>	<u>Area</u>	<u>Note*</u>
SW-21		X				Mound	1
SW-22				X		Mound	2
SW-23		X				Mound	2
SW-24		X				S Walnut Creek	2
SW-25		X				S Walnut Creek	1
SW-26		X				Woman Creek	1
SW-27				X		SID	2
SW-28					X Pond	Woman Creek	2
SW-29					X Pipe	Woman Creek	2
SW-30				X		SID	2
SW-50	X					903 Pad	2
SW-51	X					903 Pad	2
SW-52	X					903 Pad	2
SW-53	X					903 Pad	2
SW-54					X	SID	2
SW-55					X	881	2
SW-56	X					Mound (PSZ)	2
SW-57	X					903 Pad	2
SW-58	X					903 Pad	2
SW-59	X					Mound	2
SW-60		X				Mound	2
SW-61		X				Mound	2
SW-62	X					Woman Creek	2
SW-63	X					903 Pad	2
SW-64	X					903 Pad	2
SW-65	X					East Trenches	2
SW-70				X		SID	2
SW-77	X					903 Pad	2
SW-101	X					Mound (PSZ)	2
SW-102	X					Mound (PSZ)	2
SW-103	X					Mound	2
SW-132					X New	Mound	2
SW-133					X New	Mound	2
SW-C1		X				Woman Creek	2
SW-C2		X				Woman Creek	2

* 1 - Station not sampled as EMAD site-side routine sampling program

* 2 - Station sampled monthly as part of EMAD site-side routine sampling program

SID South Interceptor Ditch

ENVIRONMENTAL EVALUATION WORK PLAN (EEWP)**6.1 INTRODUCTION**

Under §106 of CERCLA or Superfund, the EPA is mandated by Congress to take appropriate action whenever "there may be an imminent and substantial endangerment to the public health or welfare or the environment because of an actual or threatened release of a hazardous substance from a facility" (emphasis added). This same language is employed in §104 although the concept of hazardous substance is broadened to include "any pollutant or contaminant." The EPA's mandate to protect human health and the environment is reiterated throughout CERCLA [e.g., §§121(b)(1), 121(c), and 121(d)] and its major implementing regulations which are contained in the NCP [40 CFR Part 300, Subpart F]. The NCP was extensively revised on March 8, 1990, (55 FR 8666) to incorporate requirements of the Superfund Amendments and Reauthorization Act of 1986 (SARA). It provides the overall framework for identifying and obtaining information on hazardous substance sites, assessing the nature and extent of the contamination, determining the risk to human health and the environment, evaluating and selecting remedial action technologies, and implementing decisions on remedial actions.

The requirement for the performance of EEs at CERCLA sites derives from NCP specifications for RI/FSs. The regulations in 40 CFR §300.430(e)(1)(G) state:

- EEs shall be performed to assess threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act.

This does not mean that EEs are to be limited to assessing risks to threatened or endangered species of plants or animals. The EEWP establishes a purpose and objectives, presents an environmental evaluation methodology, and identifies tasks to be undertaken as part of the environmental evaluation implementation process.

Detailed guidance on conducting environmental evaluations is contained in the EPA "Risk Assessment Guidance for Superfund Volume II Environmental Evaluation Manual" (EPA, 1989d). Although an "environmental evaluation" is specifically required by the NCP, the EPA uses the term "ecological assessment" as being a more precise description of the activities that actually take place in the environmental evaluation process. The EPA Manual defines an ecological assessment as "a qualitative and/or quantitative appraisal of the actual or potential effects of a hazardous waste site on plants and animals other than people and domesticated species" (EPA, 1989d). The EPA manual recognizes that ecological assessments may identify new or unexpected exposure pathways that may affect human populations.

Ecology is a branch of biological science devoted to the study of the interrelationships between organisms and their environment. In the context of any CERCLA site, human health is inextricably linked to the survival and physiological condition of nonhuman species. Thus, a risk assessment focusing on human health and an ecological assessment are, essentially, different sides of the same coin.

The EEWP prescribes how potential impacts or risks to the environment from existing OU No. 2 conditions will be evaluated, using, in part, the data collected during the Phase I RI and the Phase II RFI/RI. When the EE is implemented, it will identify and characterize the toxicity and levels of hazardous substances present, the fate and transport of contaminants, and the actual or potential environmental exposure (to plants and animals).

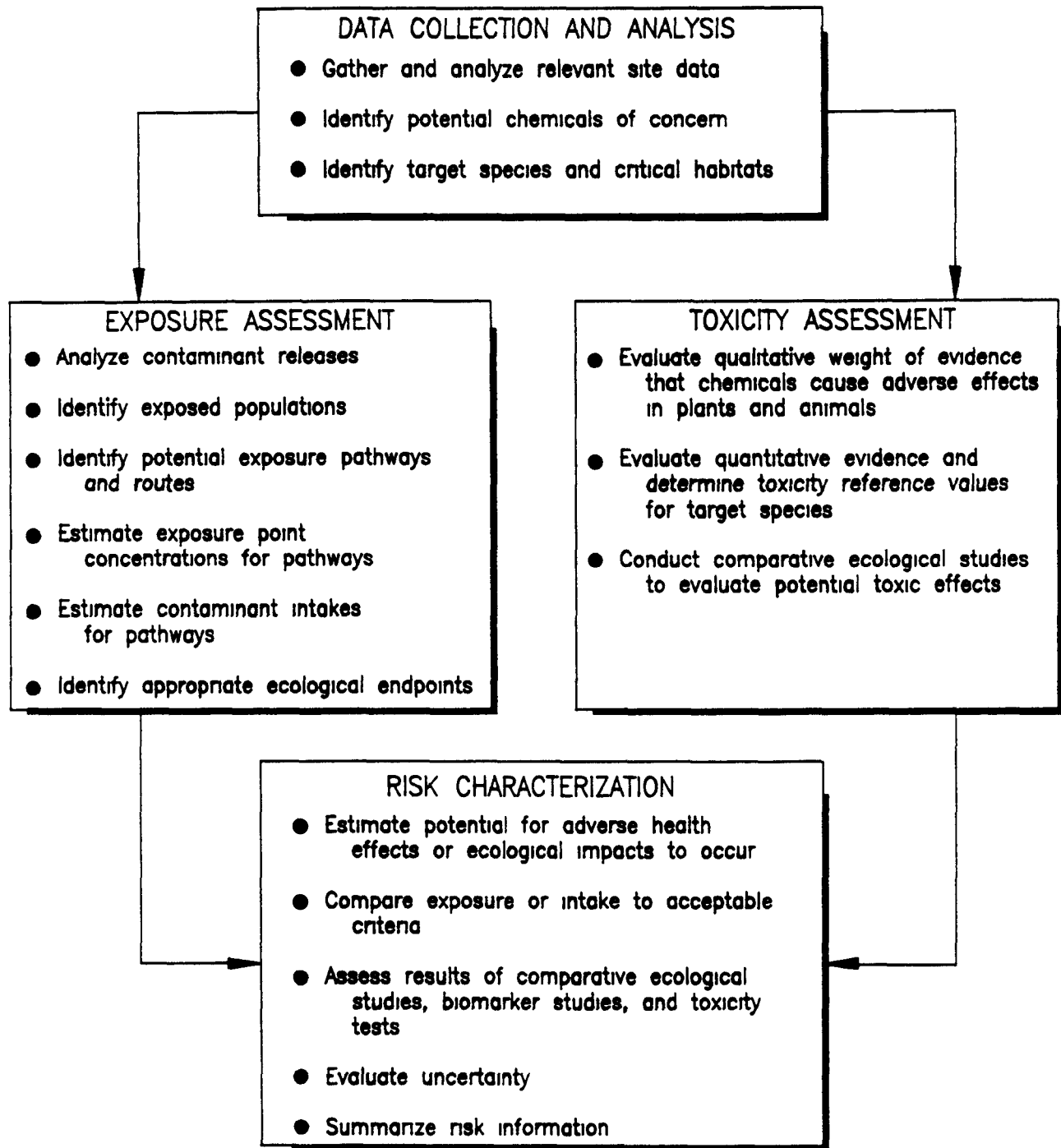
Several other operable units are geographically related to OU No. 2. The drainages downstream of OU No. 2 are separate operable units: Woman Creek, OU No. 5, and Walnut Creek, OU No. 6. An interim remedial action is being planned to treat contaminated surface water in South Walnut Creek downstream of OU No. 2 (EG&G, 1990e). Other operable units which are situated in close proximity to OU No. 2 include the 881 Hillside (OU No. 1) and several IHSSs included in the Other Outside Closures (OU No. 10), the 100 Area (OU No. 13), and the Low Priority Sites (OU No. 16). The field activities for OU No. 2 will be integrated with the EE field activities for OU Nos. 1 and 5.

The EE will address the potential environmental impacts associated with OU No. 2 under the "no-action" alternative (no remedial action taken). The EE will use the data collected in the RFI/RIFS process and supplement the data as necessary with field sampling and analysis. The EE will also provide environmental information needed to compare remedial alternatives and evaluate the mitigation of environmental risks.

6.1.1 General Approach

An EE (or ecological assessment) has much in common with the basic elements of a human health risk assessment. A risk assessment is a process for analyzing the likelihood an adverse effect will occur, the magnitude and intensity of that effect, and its spatial and temporal distribution. The basic steps in CERCLA site risk assessment for determining risk to either human populations or the environment are basically the same: contaminant identification, exposure assessment, toxicity assessment, and risk characterization (Figure 6-1). In an ecological assessment, this is accomplished through evaluating site characteristics, determining the nature and extent of contamination, identifying the actual exposure or potential for exposure of plants and animals to contaminants, selecting ecological measurement "endpoints" to measure the ecological consequences of contaminant release, and assessing toxicity through dose-response techniques.

This EEWP undertakes a comprehensive approach to performing an ecological assessment including establishing objectives, developing an overall investigation methodology, implementing the work plan, and



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Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)
MAJOR STEPS IN DEVELOPING AN
ECOLOGICAL RISK ASSESSMENT

FIGURE 6-1

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producing and documenting the results. The EEWP is based on guidance provided in the EPA EE Manual (EPA, 1989d) and other guidance documents (see list of examples in Table 6-1)

A comprehensive methodology for performing an EE is detailed in Section 6.2. The procedures recommended provide a means of determining and measuring ecological risks in a systematic, controlled, and step-by-step manner that can be used in subsequent efforts to reduce or manage the risk. While the EEWP structures the methodology for conducting the environmental evaluation of OU No. 2, it does not attempt to define the operable unit either in terms of contamination extent or ecological characteristics, this will be accomplished during the actual implementation of the EE.

This EEWP also provides a framework for determining additional data needs and identifying the techniques (including sampling and analysis) to be employed in determining ecological risks. It provides a means for both quantitative and qualitative estimates of ecological effects such as reductions of biological growth or productivity, and changes in community composition.

By implementing the methodology described in Section 6.2, the subsequent EE will be able to determine the nature and extent of adverse effects on local ecosystems resulting from contaminants present at OU No. 2. Depending on the adequacy of the database, the ecological assessment has the potential for use of statistical, stochastic models to quantify the relationship of initial events (e.g., contaminant release) with probable ultimate effects (ecological consequences).

6.1.2 Scope of the Environmental Evaluation Work Plan

The principal focus of this EEWP is on the basic methodology for performing an ecological assessment. This is because an understanding of the environmental assessment process is critical to implementing the tasks described in Section 6.3. The environmental evaluation, as described in this EEWP, will draw conclusions about whether or not the objectives of the evaluation were achieved and identify the limitations of the analysis. The ecological assessment process prescribed (Figure 6-1) has been used at other sites and in other situations and is generally accepted by the scientific community.

EEWP implementation is presented in Section 6.3 as separate tasks. The implementation plan will be used to control the structuring and implementation of the various tasks. The ultimate scope of the EE is contingent on the availability of existing data and on the progress of the field investigations, it should be reviewed regularly as the evaluation process proceeds. Section 6.4 describes the basic content of the Environmental Evaluation Report (EER) that will result from the EE process.

TABLE 6-1

**EXAMPLE U S ENVIRONMENTAL PROTECTION AGENCY
AND U S DEPARTMENT OF ENERGY GUIDANCE DOCUMENTS
AND REFERENCES FOR FIELD INVESTIGATIONS
AND ENVIRONMENTAL EVALUATIONS**

- Barnthouse, L.W , G W Suter, S M Bartell, J J Beauchamp, R H Gardener, E Linder, R V O'Neill and A E Rosen, 1986, User's Manual for Ecological Risk Assessment, Environmental Sciences Division, Publication No 2679, ORNL-6251
- DOE, 1988a, Comprehensive Environmental Response, Compensation, and Liability Act Requirements, DOE Order 5400 YY, Draft, September 1988
- DOE, 1988b, Radiological Effluent Monitoring and Environmental Surveillance, DOE Order 5400 XY, Draft, September 1988
- DOE 1990b, Radiation Protection of the Public and the Environment, DOE Order 5400 5
- EPA, 1988a, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA Interim Final, Office of Emergency and Remedial Response, Washington, D C , OSWER Directive 9355 3 01, October, 1989, EPA/540/G-89/004
- EPA, 1988c, Superfund Exposure Assessment Manual, Office of Emergency and Remedial Response, Washington, D C , EPA/540/1-88/001
- EPA, 1988e, Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, Office of Emergency and Remedial Response, Washington, D C , EPA/540/G-88/003
- EPA, 1988f, Technological Approaches to the Cleanup of Radiologically Contaminated Superfund Sites, Office of Research and Development, Washington, D C , EPA/540/2-88/002
- EPA 1989c, Ecological Assessment of Hazardous Waste Sites, a Field and Laboratory Reference Document, Environmental Research Laboratory, Corvallis, Oregon, EPA 600/3-89/013
- EPA, 1989d, Risk Assessment Guidance for Superfund Volume II Environmental Evaluation Manual, Interim Final, Office of Emergency and Remedial Response, Washington, D C , EPA/540/1-89/001
- EPA, 1989e, Exposure Factors Handbook, Office of Health and Environmental Assessment, Washington, D C , EPA/600/8-89/043

6 1 3 Purpose and Objectives of the OU No 2 Environmental Evaluation

The overall purpose of an EE of the OU No 2 area is to document a qualitative and, where possible, a quantitative assessment of actual or potential threats of damage to the environment including protected wildlife and vegetation species, habitats, or sensitive ecosystems. This purpose is consistent with the mandates of CERCLA/SARA and the IAG which states in Part 3 that one of its purposes is to ensure that "an appropriate response action is taken and completed as necessary to protect the public health, welfare, and environment." The purpose of the EEWP is to establish a scientifically credible procedure to be followed and implemented during the performance of the EE for OU No 2.

The EE will provide decision makers with information required to determine risk to the environment associated with contaminant migration from OU No 2 as it exists and if nothing is done to remediate the site. It can also be used to determine whether or not contamination at OU No 2 requires remedial action and to predict potential effects of those actions on the environment. In addition, the EE can suggest future strategies for monitoring the effectiveness of any remediation accomplished at or near the site.

The EE for OU No 2 has multiple objectives. They are to evaluate:

- Ecological characteristics of OU No 2 and its area of influence
- Kinds, forms, and quantities of contaminants of concern
- Means of potential or actual releases of contaminants
- Habitats potentially affected and populations potentially exposed to contaminants
- Exposure pathways to potentially sensitive populations
- Actual or potential ecological effects and the overall nature of the risk

6 2 ENVIRONMENTAL EVALUATION METHODOLOGY

This section identifies and discusses the principal components of the EE for OU No 2. They are presented in the sequence that would normally be followed in performing an ecological assessment. The major portion of the EE will be devoted to assessing ecological risks, environmental analyses (Section 6 2 2), toxicity assessment (Section 6 2 3), and risk characterization (Section 6 2 4).

6 2 1 Data Evaluation and Analysis

Site-specific (Rocky Flats Plant) and operable unit-specific (OU No 2) data and information collected during the Phase I RFI/RI program and prior studies by the DOE and the Rocky Flats Plant operating contractors will be reviewed and evaluated. Likewise, reports on the general area and scientific information on ecological processes related to this assessment (e.g., mobility of uranium in aquatic ecosystems) will be reviewed. These data and reports will be collected, analyzed, and compiled as source documents. The principal objective of this effort is to determine what existing information can be used for the EE and define additional data requirements. The Phase I RI and Phase II RFI/RI programs should provide the majority of the site-specific data needed on surface water, ground water, soils, and air quality. Previous environmental studies should provide the general ecological information. However, site-specific ecological data and estimates of contaminant and energy transfer in the OU No 2 area will likely require additional investigations and additional data on sediments and sediment transport.

In addition to the documents listed in Table 6-1, the following sources will be used to acquire information

- Project files maintained by Rockwell International and EG&G
- Project reports and documents on file at the Front Range Community College Library and the Colorado Department of Health
- DOE documents and DOE orders
- The Phase I RI database
- The Rocky Flats Environmental Impact Statement (EIS) database
- Data from ongoing environmental monitoring and NPDES programs at the Rocky Flats Plant
- Studies on radionuclide uptake, retention, and effects on plant and animal populations conducted by the University of Colorado and CSU
- Scientific literature, including ecological and risk assessment reports, at DOE facilities Oak Ridge National Laboratory, Los Alamos National Laboratory, and the Savannah River Project
- The IM/IRAP

Several of the scientific reports that will be used are cited in various subsections of this EEWP, including the appropriate sections of this Phase II RFI/RI Work Plan and the Final EIS on the Rocky Flats Plant (DOE, 1980). The references cited in this EEWP are presented in the list of references.

6 2 2 Environmental Analyses

The biotic and abiotic components of the existing ecosystems will be described and analyzed to determine the impacts associated with the release of contaminants. This analytical process includes characterizing the principal ecosystems in the area (Section 6 2 2 1), determining which biological populations or communities are at risk (Section 6 2 2 2), and identifying the exposure pathways to biological receptors (Section 6 2 2 3).

The environmental analysis will be combined with the data evaluation and analysis process (Section 6 2 1) to determine specific data/information requirements for completing the EE. The field investigations, sampling, and analytical work to be undertaken to fill these data gaps are discussed in Section 6 2 2 4.

6 2 2 1 Ecosystem Characterization

The ecosystems at the Rocky Flats Plant site, in the high plains region along the foothills, include arid grasslands on alluvial flats and fans interspersed with creek drainages and riparian zones. Ponds and canals have been constructed within the drainages and off site for runoff control and water retention purposes. These ecosystems will be inventoried and described to characterize the biotic resources and principal abiotic components within the Rocky Flats Plant area.

In general, there are three levels of ecological organization to be characterized: populations, communities, and ecosystems. Each level has its own dimensions of extent, structure, and change. This EE will place more emphasis on assessing impacts at the population and community levels. The inherent variability in natural systems is less at these lower levels of organization, thus, the ability to obtain valid quantitative data on populations and communities within the timeframe planned for the EE process is more feasible at this level than at the ecosystem level. Population dynamic parameters such as mortality and recruitment, and community endpoints such as species diversity and productivity, will be used to assess the impacts of contaminants. In determining the effects of the contaminants on biota, an understanding of the chemical, energy, and nutrient cycles in the ecosystems will be necessary to describe and analyze contaminant uptake and fate in the food chains.

The ecosystem characterization process includes inventorying and characterizing the terrestrial and aquatic biota in the area, describing the habitats that support the growth and existence of these biota, and defining the flow of nutrients and energy through the food webs of the ecosystem. The aquatic ecosystems are small and discrete within the OU No. 2 area. Terrestrial biotic components are more widespread and diffuse, consisting of plants and animals above the land surface, and roots and soil biota below ground.

Plant and Animal Species and Population

Field investigations and existing reports will be used to determine which plants and animals make up the biological components of the ecosystems at the Rocky Flats Plant. The primary objective will be to provide the best possible estimates of populations in the area, commensurate with the accessibility of study areas and the time and personnel available. The amount, type, reliability, and currency of the data may vary according to species, time, and place.

Inventories of the terrestrial plants, fish, and benthic macroinvertebrate communities will be very comprehensive. For other taxonomic groups, the species inventories will be based on existing reports, state and Rocky Flats Plant records, and a list of species observed during field programs. Certain species and populations will be selected for study based on criteria including, but not limited to, the following:

- Value as habitat quality indicators
- Local significance, such as economic or recreational value, of the species/population
- Potential for the species/population to be impacted, and the ease of measuring the impact or stress
- Potential future conflict with Rocky Flats Plant operations or remediation activities
- Critical nature of the habitat or sensitivity of the species/population (e.g., wetlands or threatened/endangered designations)

Each species or population selected for detailed study will be inventoried at the appropriate season to properly evaluate procedures and to maintain meaningful historical records. The goal will be to produce inventory information with the degree of reliability needed to effectively evaluate impacts at the environmental level.

Habitats

Available habitat is defined as the surface area capable of providing direct life support for an evaluation species (U.S. Fish and Wildlife Service, 1981). The areal extent and potential for impacts resulting from contaminants at OU No. 2 on available habitats will be assessed.

Factors which may potentially affect habitats present at the Rocky Flats Plant would be addressed. These include:

- Direct or indirect exposure to site-related contaminants due to transport from the source

- Physical disruption of ecosystem processes due to contaminant interference with natural biochemical, physiological, and behavioral processes
- Physical disruption of the habitat due to the site's design or operation
- Physical or chemical disturbances or destruction due to cleanup or remedial activities
- Other stresses not directed related to the site (such as extreme weather conditions)

Food Webs

Energy and nutrients flow through ecosystems by means of complex interactions between organisms known as food chains and food webs. Food chains describe the transfer of energy and nutrients from one organism to another as one consumes or decomposes the other. Food chains selected for the EE will represent the five major trophic levels

- Primary producers
- Primary consumers (herbivores)
- Secondary consumers (omnivores)
- Tertiary consumers (carnivores)
- Decomposers

Food webs are interconnecting food chains which realistically describe the complex system of pathways by which the flow of energy and nutrients takes place in nature. A general discussion will be included to explain how the selected food chain(s) interrelate with the aquatic and terrestrial ecosystems (both above and below ground) found at the Rocky Flats Plant and in the vicinity of OU No. 2

6.2.2.2 Populations at Risk

The terrestrial and aquatic species in the Rocky Flats Plant area have been described by several researchers (Weber, et al., 1974, Clark, 1977, Quick, 1964, Winsor, 1975) and summarized in the Final EIS for the Rocky Flats Plant Site (DOE, 1980). Species lists are presented in Appendix A of the EIS. In addition, terrestrial and aquatic radioecological studies conducted by CSU and DOE (Rockwell International, 1986f, Paine, 1980, Johnson, et al., 1974, Whicker, 1979, Little, 1976, and Hiatt, 1977), along with annual monitoring programs at Rocky Flats Plant, have provided information on the plants and animals in the area and their relative distribution.

The above resources, discussions with Rocky Flats Plant and Colorado Division of Wildlife (DOW) personnel, and on-site surveys will be used to determine the presence and distribution of plants and animals with respect to OU No. 2. Distribution of plants and animals within, upgradient, and downgradient of the unit will be defined to fine-tune the ecological impact assessment approach. The process of determining which populations are at risk involves sampling specific groups of organisms (e.g., benthic macroinvertebrates, soil microbes and prairie grasses), target species (e.g., fathead minnow and deer mice), and critical habitats (e.g., wetlands) as described in the EE FSP (Attachment 2.0).

Target species, target communities, and critical habitats will be selected for sampling using the following criteria:

- Susceptibility of the species, community, or habitat to the contaminants associated with OU No. 2
- Relationships between the target species, community, or habitat and the exposure pathways
- Degree of difficulty in accurately measuring the desired endpoint in that species or community
- Ability to define adequate reference and on-site test areas for the target species or community
- Amount of information in the scientific literature on the target species, community, or habitat, and the ecological significance of the species, community, or habitat
- Degree of difficulty and costs involved in conducting the necessary field sampling and laboratory analytical programs
- Potential for bioaccumulation of the contaminant of concern in the target species or community

Based on a preliminary review of the information available, some likely target species, communities, and critical habitats are presented in Table 6-2. The more practical target species and communities will be studied, at least during the initial stages of the ecological assessment. The communities and habitats on this list may change if data collection or related research indicates that other species are also important. The results of the initial ecological assessment will also direct later studies or indicate which communities need further assessment.

Wetlands are known to be productive habitats that support a relatively diverse assemblage of plants and animals. Wetlands, therefore, will be considered a critical habitat for this EE. Threatened and endangered species automatically fall within the "populations at risk" category and deserve special attention. However, prior studies indicate there may be no federally listed threatened or endangered species within the boundaries of the Rocky Flats Plant (DOE, 1980, 1990a). The conclusions of these studies will be checked during the OU No. 2 EE. The project staff will also consult with the Colorado DOW to determine if there are any species of special concern from the state's perspective.

TABLE 6-2

**POTENTIAL POPULATIONS/COMMUNITIES,
HABITATS, AND TARGET SPECIES
FOR ASSESSMENT OF ECOLOGICAL IMPACTS
AT THE ROCKY FLATS PLANT OPERABLE UNIT NO 2**

Population/Community and/or Habitat	Species/Organism
Periphyton	Diatoms Green Algae Blue-green algae
Benthic Macroinvertebrates	Mayflies Caddis flies Chironomids
Fish	Fathead minnow Bluegill
Herbivores	Deer Mice Northern pocket gopher Microtines
Carnivores	Long-tailed weasel Red fox Coyote
Grasses	Western wheatgrass Blue grama
Shrubs/Forbs	Yucca Snowberry
Trees	Cottonwood
Wetlands	Willows Cattails Sedges
Soils	Roots Microbial biomass

6 2 2 3 Pathway Analysis

An exposure pathway determines how a contaminant can move from its source to a receptor in the environment. A complete exposure pathway has five components:

- Contaminant source
- Mechanism for contaminant release
- Environmental transport medium
- Exposure point (receptor location)
- Route of exposure (mechanism for intake)

To qualify as a potential exposure pathway, all components of the pathway must be present. Possible exposure pathways from the sources within OU No. 2 to plants and animals in the area will be assessed and several pathways will be selected for detailed analysis. The selected pathways will represent actual field conditions. It is anticipated that many exposure pathways cannot be quantified because transport rates, intake rates, or other data are not available. Exposure pathways selected for analyses will include some or all of the target species. Pathways will be developed for the five transport media: soil, ground water, surface water, sediments, and air. The first four media will be sampled as described in Section 5.0 Field Sampling Plan. Air is currently being sampled for plutonium, PM10, and TSP as part of the non-RAAMP site wide study.

The logical exposure points at and near OU No. 2 will be identified based on an iterative process of identifying the biological receptors in areas potentially contaminated and determining the contaminant concentrations at likely exposure points, depending upon the receptors selected. Contaminant concentrations at the exposure points will be measured directly, when possible, or determined by modeling the release of contaminants from on-site sources. When appropriate, the chemical transport and fate of contaminants will be evaluated using procedures similar to those presented in the EPA Superfund Exposure Assessment Manual (EPA, 1988c).

Many of the potential human exposure routes for constituents of concern at OU No. 2 also exist as possibilities for the local wildlife populations. These include inhalation of volatilized contaminants in air, inhalation of dust from contaminated soils, and dermal exposure to contaminated surface waters and soils. Since wildlife at or near OU No. 2 derive a major portion of their food supply from vegetation or prey species, migration of constituents into the food web with the subsequent possibility of biomagnification may provide a significant indirect route of exposure.

Quantitative analysis will utilize established EPA models for rate of transfer and fate of contaminants (EPA, 1988c) and for calculating specific intakes for each target species selected for quantitative evaluation. Standard equations for estimating human intakes (EPA, 1989a) may be used, where appropriate, to estimate intake rates for terrestrial vertebrates.

6.2.2.4 Field Investigations, Sampling, and Analysis

Because field investigation methods and sampling and analysis techniques are so critical to the scientific credibility of the EE, this section provides a detailed discussion to these topics. Qualitative field surveys, comparative ecology studies, toxicity testing, and bioaccumulation/biomarker studies are addressed. The EE FSP (Attachment 2.0) provides detailed information on sampling design, location, and intensity.

A preliminary assessment of the operational history of the Rocky Flats Plant and OU No. 2, and a review of pertinent site characterization sections in available reports, indicates that completion of the EE requires

- 1 Source characterization including presence, absence, and concentration gradients of contaminants
- 2 Exposure pathway characterization including contaminant release, media transport, and receptor exposure mechanisms
- 3 Determination of the presence, absence, and distribution of receptors
- 4 Assessment of toxicity or stress on the terrestrial and aquatic ecosystems present at the site

The physical and chemical data required to address items 1 and 2 above, with some exceptions, will be available from the Phase I RI and Phase II RFI/RI field investigations discussed in Section 5.0. Additional data on sediments adjacent to and downgradient of OU No. 2 will be collected to supplement planned investigations of potential impacts on aquatic ecosystems.

In order to address items 2, 3, and 4 above, additional data will be acquired on the specific species and populations in the area. The general biological components of the Rocky Flats Plant area have been described by previous investigations (DOE, 1980; Rockwell International, 1986f). However, more site-specific data (e.g., specific to OU No. 2) and a more thorough understanding of the population and community dynamics are necessary to complete the EE. For example, location-specific information on species diversity, biomass, cover class, and production within prairie grass communities at uncontaminated reference areas and at contaminated areas near OU No. 2 will be used to assess ecological risks.

The EE sampling methods will conform to the guidance manuals and sampling protocol references listed in Table 6-1 and the references cited at the end of Section 6.4. Evaluation techniques will include qualitative field surveys, comparative ecological studies, toxicity assessment/testing, and bioaccumulation studies. Each of these techniques contributes a different type of information to the evaluation.

Qualitative Field Surveys

Field surveys will be conducted early in the process since the main objective is to get site-specific information on the occurrence of plant and animal species and habitat types in order to fine tune sampling programs and complete a "reality check" on exposure pathways. Field surveys will also be used to select the best locations for reference (control) sampling areas. The field surveys will be conducted by qualified terrestrial and aquatic ecologists and will be largely qualitative. Some field instruments, such as pH, conductivity, temperature, and dissolved oxygen meters, will be used to assist in locating potential contaminant-impacted areas, but most information will be acquired through visual observations. The EE FSP (Attachment 2.0) describes the qualitative survey plans in more detail.

During the qualitative surveys, details of field observations will be recorded in field logbooks, as per the Standard Operating Procedures for the ER Program and RFI. Field biologists will record all observations of animal sightings and animal signs such as nests, burrows and scat, record locations of any sensitive habitats and wetlands, and note any evidence of stressed vegetation or visual evidence of contamination. They will also assess the suitability of different habitat types to support aquatic and terrestrial communities. In addition, field instruments will be used to search for evidence of contamination such as organic vapors in soils or obvious changes in pH, conductivity, temperature, and dissolved oxygen in surface water.

Comparative Ecology Studies

Ecological field surveys, involving comparisons of impacted and nonimpacted areas, are a potential method of establishing that ecological impacts have occurred. However, care will be taken to account for differences in the physical/chemical aspects of the reference and test areas and the natural variations exhibited by biological populations. Comparative ecological "endpoints" will be selected to assess contaminant impacts and will include productivity and diversity (Section 6.2.3.2). To maintain a valid comparison, reference areas or sites will be selected that (1) are in close proximity to the OU No. 2 area, (2) closely resemble the OU No. 2 area in terms of topography, soil composition, water chemistry, etc., and (3) have no apparent exposure pathways from Rocky Flats Plant or other sources of contamination. If possible, the reference areas for OU No. 2 will be the same as those used for adjacent operable units such as OU No. 1 and OU No. 5.

Comparative ecological studies will be directed at three aquatic and five terrestrial communities or components benthic macroinvertebrates, periphyton, fish, small mammals, grassland vegetation, plant roots and microbial biomass, invertebrates, and wetlands These were selected because

- There is extensive scientific literature available for interpreting results and making conclusions
- The communities exist in impacted and nonimpacted areas of the Rocky Flats Plant
- Standard field techniques have been developed to measure the necessary community parameters
- Surveys can be completed at reasonable costs

Free-floating phytoplankton were not selected because the small creeks and ponds at the Rocky Flats Plant provide only a limited habitat for this aquatic community Ecological endpoints such as relative abundance, species diversity, community organization, biomass, reproduction, and growth rates will be used to compare the communities at reference sites with communities in contaminated areas in or near the operable unit Reference and contaminated sites will be carefully selected to minimize the influence of chemical and physical differences between the sites

Periphyton, benthic macroinvertebrate, and fish communities will be sampled at reference and test sites Periphyton will be monitored using artificial substrates, macroinvertebrates will be sampled with Surber and Ekman samplers, and fish will be collected by electroshocking Qualitative observations on all aquatic flora and fauna will supplement the quantitative sampling Periphyton data will include colonization rates on the plexiglass substrates over a four-week exposure period Abundance, species diversity, biomass, and other parameters will be used to determine if periphyton, benthic, or fish communities within the test areas have been impacted in comparison to the reference area Physical and chemical parameters such as substrate type, current velocity, and pH will be carefully documented to account for physical/chemical influences not related to contaminant releases

The terrestrial communities will be sampled at areas within OU No 2 and at the reference sites The vegetation, animal population and components of the soil biomass will be selected for general surveys and detailed studies Species abundance, cover, productivity, vigor, and signs of stress will be used as assessment characteristics Physical and abiotic parameters such as soil types, substrate disturbance, slope, moisture regimes, and topography will be assessed for selecting sampling areas

Toxicity Testing

The actual or potential toxicity of contaminants at stations within and near OU No 2 will be assessed using three approaches: comparison of contaminant concentrations at exposure points to ARARs, comparison of existing concentrations to toxicological endpoints presented in scientific literature, and actual toxicity tests.

The initial step will be to compare average and maximum concentrations of contaminants of concern at logical exposure points (e.g., air, soil, water, and sediments) to established criteria. There are several criteria established for aquatic organisms [e.g., water quality criteria for protection of aquatic life (EPA, 1986a)] but relatively few criteria for terrestrial and soil organisms. The amount or proportion by which concentrations at OU No 2 exceed available criteria will be presented in tabular form, and the ecological significance will be interpreted.

In some cases, toxicity values are available in the literature for chemicals that have no criteria or standards. Toxicity values for contaminants of concern from the available literature, involving species of plants and animals that are known to occur at the Rocky Flats Plant, will be compared, when possible, to average and maximum concentrations of contaminants at logical exposure points. Again, more data on aquatic organisms are expected to be available than on terrestrial organisms.

Comparison of on-site concentrations to criteria or toxicity values may not be sufficient to assess the potential impact of all of the contaminants of concern at OU No 2. Also, the comparison approach does not account for potential synergistic, antagonistic, or additive effects in complex mixtures and may not adequately reflect the bioavailability of the contaminant or the physico-chemical nature of the receiving waters. For this reason, a limited toxicity testing program will be conducted as an initial phase.

The initial toxicity testing program will be limited to aquatic organisms and will include standardized acute and chronic tests with fathead minnows and *Ceriodaphnia* (EPA, 1985b, 1985c, 1989f). Water samples for toxicity tests will be collected from two stations immediately downgradient of OU No 2 (Stations SW-23 and SW-28), and from the downstream ponds on South Walnut Creek (Pond B-5) and Woman Creek Pond (Pond C-2) (see Figure 2.1 in Attachment 2.0). The water will be cooled to 4°C and shipped to the laboratory conducting the toxicity tests within 12 to 24 hours. The toxicity tests will be initiated within 36 hours of the field collection time. The duration of the static renewal acute tests will be 48 hours for *Ceriodaphnia* and 96 hours for fathead minnows. The test water will be renewed daily, and dilution water will be collected from the aquatic ecology reference station. The static renewal chronic tests will last for seven days for fathead minnows and until 60 percent of the *Ceriodaphnia* in the control vessels have three broods. Quality control procedures will conform to EPA requirements for NPDES toxicity testing (EPA, 1985b, 1989f).

The toxicity tests will be conducted during high-flow (spring) and base-flow (late summer) conditions because the influence of ground water may vary significantly under these different flow conditions. Two acute tests and two chronic tests will be conducted within one to two weeks of each other during each season. If toxicity is observed in both acute or both chronic tests at any one station, then a supplemental toxicity testing program will be designed for that location to determine if the toxicity is consistent and to determine the potential extent of the toxicant. The supplemental toxicity testing program may include on-site or in-stream tests involving indigenous fish, invertebrates, or algae. If the toxicity tests with creek or pond water indicate that the water at a given location is toxic, and physical and chemical analyses of the sediment at that location suggest that the sediment may be a source of that toxicity, then additional toxicity tests may be proposed to specifically assess the sediment.

The potential for a toxicity test involving soils and terrestrial organisms will be evaluated. If a relatively standard method is available using a species known to occur at the Rocky Flats Plant, toxicity tests will be proposed using soils from reference and test areas. Toxicity tests developed for microbes, earthworms, crickets, and grasshoppers will be evaluated (EPA, 1989f).

Bioaccumulation Studies

A bioaccumulation study will be conducted to determine if selected metals and radionuclides might be accumulating in the tissues of some of the aquatic and terrestrial organisms at the Rocky Flats Plant. Plants and animals will be sampled from the five communities used for the comparative ecology studies: periphyton, benthic macroinvertebrates, fish, small mammals, and prairie vegetation. Where possible, only one or two species within the community will be sampled to enhance the comparability between stations over time and the comparison with bioaccumulation levels reported in the literature. For example, in the fish community the most abundant minnow or dace and one species of sunfish may be used. However, for periphyton, the sample will consist of all periphyton scraped from one or more slides in the periphyton sampler. Because these organisms live in direct contact with the contaminated media (water, sediments, and soil), they are the most likely candidates to exhibit bioaccumulation. Samples will be collected from a limited number of stations that have exhibited prior contamination. If bioaccumulation is observed, the sampling program may be expanded.

The term "biomarkers" refers to the measurement of selected endpoints in individual organisms, typically physiological or biochemical responses, that serve as indicators of exposure to contaminants and/or sublethal stress. As used in this EE, bioaccumulation is considered a biomarker approach because it is a measurement of an endpoint in individual organisms that indicates exposure. However, there are several other types of biomarkers. For example, exposure to some metals such as cadmium and copper induces the synthesis of certain low molecular weight metal-binding proteins in a variety of vertebrate and invertebrate species. Thus,

the measurement of these metal-binding proteins provides a potential tool for assessing the effects of these metals

There are many advantages of using physiological and biochemical-type biomarkers in ecological assessments, including their broad applicability to many taxonomic groups, the ability to link field surveys to laboratory tests to interpret the significance of field results, and the fact that some biomarkers are diagnostic of specific contaminants. However, there is currently a lack of accepted, standardized, and tested biomarkers for many of the contaminants found at hazardous waste sites. Also, the relationship between a measured biomarker response and population-level effects has not been defined in many cases.

For the reasons listed above, only bioaccumulation studies will be included in the EE FSP (Attachment 2.0). A specific biomarker approach may be developed later if bioaccumulation of specific contaminants is observed, and there appears to be a realistic biomarker technique for assessing the environmental impact of those particular contaminants. For example, studies at Oak Ridge, Tennessee, associated with the environmental restoration program at the Oak Ridge National Laboratory, have held some success using biomarkers (Oak Ridge National Laboratory 1988, 1989).

6.2.3 Toxicity Assessment

The purpose of the toxicity assessment is to weigh the available evidence regarding the potential for particular contaminants to cause an adverse effect in exposed receptors (target species). It also provides, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. Toxicity assessments for contaminants identified at OU No. 2 will be accomplished by incorporating evidence from more than one technique, where possible. Specifically, the assessment of toxicity for plants and animals may include evidence from a dose-response assessment (a standard approach in human health risk assessments), comparative ecological surveys using endpoints of ecological significance (such as an increase in mortality rate), and toxicity tests.

Many of the difficulties that arise during EE performance begin with the validity of techniques used to answer the seemingly easy question: Does a hazard exist? The use of the term "hazard" depends on the characteristics of the contaminant of concern and the circumstances of use. The Environmental Evaluation Report (EER) will clearly define this term and discuss techniques used in determining if a hazard(s) actually exists. An example toxicological profile is included in Attachment 3.0.

6 2 3 1 Dose-Response Assessment (Extrapolation Models)

The most fundamental concept in toxicology is that a relationship exists between the dose of an agent and the response that is produced in a living organism. Dose-response assessment is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed populations. From this quantitative dose-response relationship, toxicity values (reference doses or RfDs) are derived that can be used to estimate the incidence or potential for adverse effects as a function of receptor exposure to a contaminant.

Because individuals and species accumulate contaminants differently in their tissues, environmental concentrations and uptake rates will not necessarily predict biotic concentrations. Pharmacokinetic distribution following uptake determines the concentration of a constituent that actually reaches the physiological site of action within an organism, and therefore, the likelihood of an adverse effect. For this reason, concentrations in environmental media and biotic tissues will be determined independently for some species. Based on these data, site-specific bioconcentration factors (BCFs) may be derived. If site-specific BCFs cannot be derived from the monitoring data, published and/or predicted BCFs will be utilized in the EE.

The final step in the dose-response assessment will be to evaluate the toxicity associated with contaminants. For several chemicals, toxicological data have been evaluated by the EPA or other agencies and RfDs for noncarcinogenic effects have been developed (EPA, 1987b). These RfDs are based on a survey of the current toxicological literature including both animal studies and human epidemiological studies. In cases where RfDs are not available, comparisons may be drawn between the contaminant-receptor relationship existing at OU 1 No. 2 and appropriate laboratory studies that have developed other values expressing toxicity. Examples include LD₅₀ and LC₅₀ values and growth inhibition levels.

Cancer potency factors have been developed for many contaminants that are carcinogenic in humans (EPA, 1987b). Similar factors or extrapolations have been made to some animal species. Carcinogenic potency factors are expressed as the lifetime cancer risk per mg/kg body weight per day. Therefore, exposures need to be quantified or estimated over long time periods. Where possible, the toxic effects of some contaminants will be assessed using cancer potency factors. Generally, this will be limited to vertebrate animals. It may be most appropriate for small mammals (e.g., mice) that have been the subject of, or test organisms in, numerous laboratory experiments on carcinogens.

6 2 3 2 Comparative Ecological Studies

Ecological surveys will be used during the EE to study endpoints of ecological interest in selected target species or plant or animal communities. These receptors (the target species or selected community) are the

components of the ecosystem that may or may not be adversely affected by the site-specific contaminant being studied. The measurement endpoints are the particular type of impact a contaminant is expected to have on a given receptor.

Generally, endpoints of ecological interest may be divided into four levels: individual, population, community, and ecosystem. These levels may be further refined as:

- Individual endpoints
 - Changes in respiration
 - Changes in behavior
 - Increased susceptibility to illness
 - Decreased growth
 - Death
- Population endpoints
 - Decreased genotypic and phenotypic diversity
 - Decreased fecundity
 - Decreased growth rate
 - Increased frequency of disease
 - Increased mortality rate
- Community endpoints
 - Decreased species diversity
 - Decreased food web diversity
 - Decreased productivity
- Ecosystem endpoints
 - Decreased diversity of communities
 - Altered nutrient cycling
 - Decreased resiliencies

Because of the complexity of interactions within food chains (or in a food web), and the number and variety of receptors in an ecosystem, it is impossible to assess the potential impacts to all receptors for all endpoints. Therefore, representative types of receptors and endpoints will be selected and used as indicators of potential effects on biological communities. Presently, there are no regulatory standards concerning individual assessment endpoints of biological interest for non-human aquatic or terrestrial species. There is, however, a general consensus defining adverse effects of measurement endpoints at the population level (EPA, 1989c) and to a lesser extent, at the community level. Therefore, the EE will be limited to studying ecological endpoints in selected populations and communities. These may include some functional processes such as primary productivity in grassland or fish biomass in ponds.

6 2 3 3 Bioaccumulation Studies

Measuring the accumulation of contaminants in living organisms provides direct evidence of exposure and uptake of the contaminant by the organisms, but does not necessarily equate to negative effects because many organisms tolerate some degree of bioaccumulation. Bioaccumulation, therefore, will be assessed using the field sampling results, scientific literature on the contaminant and receptor being studied, and other lines of evidence such as the comparative ecological studies. Where possible, bioconcentration factors [the ratio of the tissue concentration (fish or roots) to the environmental media concentration (water or soils)] will be determined and compared to bioconcentration factors reported in the literature. The potential for biomagnification of contaminants in higher trophic levels will also be investigated.

6 2 4 Risk Characterization

Information developed in the exposure and toxicity assessments (Sections 6 2 2 2, 6 2 2 3, and 6 2 3) will be used to characterize the risk to plants and animals from contaminants released from OU No. 2. The information will be summarized and integrated into quantitative and qualitative expressions of risk. Comparisons will be made between projected intakes of chemicals (or other exposure estimates) and toxicity (as expressed by ARARs, toxicity test results, RfDs, or toxicity values from the literature) to characterize potential noncarcinogenic effects from exposure to chemical contaminants. To characterize potential carcinogenic effects from chemical contaminants, probabilities that an individual organism will develop cancer over a lifetime of exposure will be estimated from projected intakes and chemical-specific, dose-response information. The assessment of carcinogenic effects will not be developed to the extent found in human health risk assessments; carcinogenic effects on only a few species will be presented. Estimated dose equivalents and intake rates will be compared to ARARs and other guidance to characterize potential effects from radionuclide exposure.

The risk characterization will present estimates of risk for defined exposure scenarios plus summaries of the relevant biological information, identification of the assumptions used and their limitations, and a discussion of uncertainties. The risk characterization will address risks associated with organic and inorganic (metals) contaminants and radionuclides.

6 2 4 1 Organic Contaminants

The toxicity of organic contaminants is both general and specific. Effects observed in studies of experimental animals have been dependent on a variety of factors including chemical structure, exposure level, frequency and coexposure, and subject sensitivity. Studies to date at the Rocky Flats Plant, especially those specifically related to OU No. 2, indicate that volatile organic contaminants are much more prevalent than semi-volatiles,

PCB's, and base-neutral organics. There are relatively high concentrations of several volatile organics (e.g., TCE, PCE, CCl₄, vinyl chloride, and ethylbenzene) in various environmental media (soil, surface water, sediments, etc.). In contrast, there are relatively few semi-volatile organics of concern.

Due to their high vapor pressure, volatile organics can be easily mobilized from one environmental compartment to another. They are very mobile in comparison to semi-volatiles and many inorganics. Kidney and liver enlargement are a common result of volatile organic toxicity because these chemicals induce mixed function oxidases. Prolonged exposure frequently results in damage to metabolic organs, and several volatile organics can induce carcinogenesis.

6.2.4.2 Inorganic (Metal) Contaminants

Toxicity of metals to aquatic organisms, plants, and soil-dwelling animals has been extensively researched. Scientific literature is available for assessing potential impacts. This is especially true for aquatic organisms.

There are a few general principles that contribute to understanding the pathophysiology of metal toxicity. Most metals affect multiple organ systems. The targets for toxicity are specific biochemical processes (enzymes) and/or membranes of cells and organelles. The toxic effect of the metal usually involves an interaction between the free metal ion and the toxicological target. There may be multiple reasons why a particular toxic effect occurs. For example, the metabolism of the toxic metal may be similar to a metabolically related essential element. Cells that are involved in the transport of metals, such as gastro-intestinal, liver, or renal tubular cells, are particularly susceptible to metal toxicity (Goyer, 1986).

The Phase I RI field investigations indicate that there are several metals in surface water, ground water, and soils at OU No. 2. Investigations are still in progress to determine which metals are present in concentrations exceeding expected natural background concentrations. However, it is likely that several metals which are toxic to plants and animals are contaminants associated with releases from OU No. 2. For example, cadmium, chromium, zinc, and vanadium have been observed in several media at concentrations that are likely above background.

The water quality data from the Phase I RI and Phase II RFI/RI field investigations (Section 5.0) will be compared to the water quality criteria for the protection of aquatic life (EPA, 1986). Additionally, the information in U.S. EPA's Quality Criteria for Water 1986 (EPA, 1986), the supporting ambient water quality criteria documents (e.g., zinc, EPA, 1987c), and contaminant hazard reviews (e.g., chromium, Eisler, 1986) will be used to evaluate the potential toxicity of metals to aquatic target species. The EPA ambient water quality criteria documents (e.g., EPA, 1987c) also provide bioconcentration factors (BCF = concentration of a contaminant in tissue/concentration of a contaminant in the media) and body burdens (tissue residue) from other studies.

which can be compared, when available, to tissue residues and calculated BCFs for fish or macroinvertebrates in the Rocky Flats Plant area. The contaminant hazard reviews and other toxicological literature will also be used to evaluate the potential toxicity of metals to terrestrial plants and animals, again emphasizing the information relative to the target species selected for this EE.

Toxicity tests will be conducted to supplement the toxicity evaluation based on comparing on-site concentrations to criteria. The comparison-to-criteria approach does not consider synergistic/antagonistic effects that can occur when certain metals are present at the same time, or the influence that organic contaminants or other substances may have on metal toxicity.

6.2.4.3 Radionuclides

The radionuclides of concern associated with OU No. 2 are plutonium and uranium, with smaller amounts of americium. Other radionuclides that are potential contaminants in water are cesium-137, strontium-89, -90 and tritium (see Section 2.3). However, the Phase I RI data for these three radionuclides are inadequate to assess contamination.

The dispersion of radionuclides from the Rocky Flats Plant into air, soil, water, and biota have been studied and summarized in a report on the radioecology and airborne pathway at the facility (Rockwell International, 1986f). Also, the ecological effects of plutonium in the environment at the Rocky Flats Plant were assessed on biota by measuring biological parameters and by pathological examination (Whicker, 1979, Paine, 1980). The conclusions of these studies indicate that plutonium is relatively immobile in the environment, and that no differences in biological attributes could be related to plutonium levels found in environmental media at the Rocky Flats Plant.

Specific ARARs for radionuclide contamination in environmental media are generally calculated for human health protection. Very few studies have been conducted to relate the effects of radionuclides on non-human receptors. Most plant populations are less sensitive than animal populations to radionuclides or their radiation. In most cases, the living biomass of plants in the grasslands at the Rocky Flats Plant is small in relationship to organic matter and turnover is rapid. Most species of wildlife are also short-lived and, therefore, not sensitive to radiation effects. The exceptions are a few long-lived predatory bird and mammal species which may be sensitive to radiation effects. Soil microbes, invertebrates, or anthropods may be sampled and used as indicators of plutonium uptake and possible bioaccumulation in the terrestrial environment. However, these populations have rapid turnover rates with respect to numbers, nutrients, and energy. They may or may not be good indicators of contaminant effects in many cases.

The aquatic ecosystems at the Rocky Flats Plant may exhibit bioaccumulation of radionuclides. They will be sampled and evaluated during this EE. Previous sampling of aquatic communities in ponds and lakes near the Rocky Flats Plant has revealed some bioaccumulation in seston (the mass of various living and nonliving substances in the water column) but, apparently, no transfer of plutonium within the food chain (see Section 2.3).

Literature searches will be conducted to locate toxicity studies on plant and animal populations involving plutonium and americium. Also, studies investigating the carcinogenicity and other toxic effects of plutonium, but involving high doses in controlled laboratory conditions, will be evaluated to see if any of the results might be applicable to conditions at OU No. 2.

6.2.4.4 Risk Analysis

The risk posed by contaminants released from OU No. 2, assuming "no action," will be assessed using one or more techniques. Six different methods of analyzing risks to the environment from contaminants present at OU No. 2 are discussed in this subsection.

- 1 Comparing exposure point concentrations to published criteria or doses with known adverse effects
- 2 Evaluating toxicity test data from laboratory studies of aquatic and terrestrial organisms, using data from studies involving the same species or closely related species as found at the Rocky Flats Plant (e.g., fathead minnows)
- 3 Comparing populations of plants or animals existing in contaminated areas to the same populations in uncontaminated or "reference" areas
- 4 Using a quantitative dose-response assessment for a limited number of species
- 5 Comparing bioaccumulation of some contaminants in organisms collected from OU No. 2 to bioaccumulation of the same contaminants reported in the literature
- 6 Applying quantitative fault/event tree analysis
- 7 Development of a food web pathways model

The first method, referred to as the quotient method, involves comparing the concentrations of a contaminant at known exposure points to published criteria or a regulatory standard (ARARs), or to a dose known to cause adverse or toxic effects (for example an LC_{50}). As discussed in previous sections, the risk from chemical or radiological contaminants to populations in nature, based on toxicity tests or epidemiological data, are not available in many cases. Therefore, the quotient method can be used, employing criteria that have been established from the toxicological literature.

A second risk analysis method involves comparing data from laboratory toxicity tests on standard species to native species, such as laboratory mice to deer mice in the grassland near OU No 2. Appropriate correction factors must be applied to incorporate variability among species, life stages, and so forth, and account for differences between conditions in the laboratory and in the natural environment. This method will yield an indication of what concentration of a contaminant will be a safe level, below which no adverse effects are expected to occur. A logical refinement of this method would be to conduct toxicity tests on native species using water or soil from the OU No 2 area, simulating environmental conditions as much as practical.

A third method is based on comparing on-site populations in known or expected contaminated areas to similar populations at reference (upgradient uncontaminated) areas. Population parameters (e.g., growth rates, reproduction rates, and mortality rates) or community parameters (e.g., species diversity, standing crop, and productivity) are used to assess the differences between the populations in impacted and non-impacted areas. At the concentrations of contaminants expected in the Rocky Flats Plant ecosystems, this method may not be sensitive enough to unequivocally determine consequences.

In the fourth method, if the ratio of the daily intake to an acceptable intake exceeds 1.0 (unity) for the defined exposure scenario, there is an indication that the exposed species may be subject to an adverse impact and that further investigation should be undertaken. If the ratio is below unity, it is generally assumed that no adverse impact will occur. This method is comparable to the human health risk assessment approach.

In the fifth method, exposed populations are examined to determine if the tissue concentrations are greater than environmental media concentrations. The tissue to media ratio is referred to as the BCF. Tissue concentrations can also be estimated from published BCF sources if the on-site media concentration is known.

A sixth method for analyzing risk that will be considered for possible use at OU No 2 is the use of fault/event tree analysis. This process examines the release scenarios, pathway analyses, and possible consequences to the ecosystems in a step-wise sequence. It uses logic diagrams in phased scenarios to which probabilities can be assigned. This is a quantitative probability method in which uncertainties can also be quantified.

A seventh method includes development of a site specific pathways model based on the ecological field investigation and inventory. This exposure-receptor pathways model will be used to evaluate the transport of contaminants from sources to biological receptors. This model will provide an initial determination of the movement and distribution of contaminants, the likely interactions among ecosystem components, and expected ecological effects.

Other methods that have been used for ecological assessment, such as ecosystem modeling are not appropriate for use at OU No 2. These methods involve the use of computer simulation and require extensive field verification of the assumptions in the modeling.

6.2.4.5 Uncertainty Analysis

All risk estimates are dependent on numerous assumptions and the many uncertainties that are inherent in the EE process. In any evaluation of the level of risk associated with a site, it is necessary to address the level of confidence or the uncertainty associated with the estimated risk. Uncertainties are associated with both toxicity information (e.g., hazard identification and dose-response assessment) and exposure assessment information. Consequently, factors that may significantly increase the uncertainty of the EE results will be identified and addressed in a qualitative and, where possible, a quantitative manner.

Three qualitatively distinct sources of uncertainty endemic to any EE are inherent variability, parameter uncertainty, and model error. It is essential to distinguish between these uncertainty parameters since they differ with respect to feasibility of quantification and degree of possible reduction through research or environmental monitoring (Barnthouse, et al., 1986).

Inherent Variability

Constraints on the precision with which variable properties of the ecosystem can be measured will limit the precision with which it will be possible to predict the ecological effects of stress. The concentration of a constituent in a medium varies unpredictably in fate and transport (space and time) because of essentially unpredictable variation in meteorological parameters such as precipitation and wind direction. The spatiotemporal distributions and sensitivities to stress of the target species in nature are similarly variable. This variability can be quantified for many characteristics of the physical environment that influence the constituent's environmental fate (Barnthouse, et al., 1986). For the OU No 2 EE, actual analytical data will be used as the estimates of constituent soil and water concentrations. Variable biological aspects of the ecosystem will be more difficult to quantify.

Parameter Uncertainty

Errors in parameter estimates may introduce additional uncertainties. Parameter values from the scientific literature may be estimated from structure-activity relationships or from taxonomic correlations that are not corrected for site-specific parameters. In addition, direct laboratory measurements may be subject to error. Unlike inherent variability, however, uncertainties due to parameter error may be reduced by increasing the

precision of measurements or by replacing extrapolated parameter estimates with direct measurements where possible

Model Errors

Model errors will constitute the least tractable source of uncertainty in the EE. Major sources of model error are (1) using a small variable to represent a large number of complex phenomena, (2) choosing incorrect functional forms for interactions among variables, and (3) setting inappropriate boundaries or limits on the model universe (Barnhouse, et al, 1986). Although these errors cannot be completely eliminated from the EE, one of the EE objectives will be to reduce them as much as possible.

6.3 ENVIRONMENTAL EVALUATION WORK PLAN IMPLEMENTATION

This section describes six different tasks under which the EE will be organized and performed. The tasks address data evaluation and analysis, field investigations including field sampling and analysis, the ecological risk assessment, and preparation of the EE report. This task structure will be employed as the principal vehicle for scheduling and budgeting of the entire EE process. Program flexibility will be required as the nature and scope of any particular task may need to be modified depending on the results of the review of existing data, field investigations, and the sampling and analysis program.

6.3.1 Task 1 Review of Existing Information

The depth and breadth of existing data and site information pertaining to OU No. 2 and its immediate vicinity are not currently known. Several reports, including the Phase I RI and the Phase II RFI/RI Work Plan, are available for OU No. 2. There are also monthly and annual Rocky Flats Plant Environmental Monitoring Reports, as well as some rather generic information on plant and animal species and habitats, including wetlands.

As the list of references included in this EEWP indicates, there are a number of sources of useful information in the scientific literature and in reports prepared by Colorado state agencies and universities. The collection and review of the existing database on wetlands and floodplains, threatened and endangered species, meteorology, geology, soils, hydrogeology, hydrology, geomorphology, and other topics will in itself be a significant task. It will guide how each of the subsequent tasks are to be conducted.

6 3 2 Task 2 Data Evaluation and Analysis

As discussed in Section 6 2 1, site-specific information and the scientific literature will be reviewed and analyzed to provide a comprehensive data source for the EE. The data evaluation and analysis task will review the existing database to determine, among other things, the following

- Identification and concentration of contaminants of concern (organics, heavy metals, and radionuclides)
- Site-specific characteristics (climatology, surface water, ground water, soils, geology, hydrology, geochemistry, and terrestrial and aquatic ecosystems)
- Adequacy of data and additional data needs

The nature, extent, and scientific credibility of the existing database will, in great part, dictate the parameters for the field investigations in Task 3

6 3 3 Task 3 Field Investigations (Including Field Sampling)

The approach to field investigations, including field sampling and analysis, is described in detail in Section 6 2 2 4 and Attachment 2 0. Field investigations will be adequate to determine (1) contaminant source characterization, (2) exposure pathway characterization, (3) presence, absence, and distribution of biological receptors, and (4) assessment of toxicity or stress on terrestrial and aquatic ecosystems. While data required to address items (1) and (2) are assumed to be available from the Phase I RI and the planned Phase II RFI/RI investigations discussed in Section 5 0, some additional data (e.g., information on sediments) will need to be collected in the field. Also, additional data will need to be developed for biological species in order to develop a thorough understanding of population dynamics. Specifically, information will be developed in the field on species diversity, biomass, sensitive habitats, and food webs. All these data will be needed to assess populations at risk.

Field investigations will include each of the items addressed in Section 6 2 2 4

- Qualitative field surveys (including sensitive habitats such as wetlands or riparian vegetation)
- Comparative ecology studies (involving comparisons of impacted and nonimpacted reference sites)
- Sampling of periphyton, benthic macroinvertebrates, and vegetation
- Toxicity testing

Once Tasks 1 and 2 have been completed and the additional data needs specified, the field sampling plan (Attachment 2.0) will be reviewed and modified if necessary. The plan describes sampling techniques, field instrumentation, and data management. It will also be integrated with the health and safety plan.

6.3.4 Task 4 Ecological Risk Assessment

The assessment of risk to terrestrial and aquatic organisms and habitats will be accomplished through the environmental analysis, toxicity assessment, and risk characterization described in Sections 6.2.2, 6.2.3, and 6.2.4. The environmental analysis will characterize ecosystems, populations at risk, and potential contaminant pathways. The ecosystem characterization will include biotic resource inventories (wildlife, vegetation, and aquatic organisms) and abiotic components (soils, moisture, temperature). While population information exists for species present at the Rocky Flats Plant, the amount, type, currency, and reliability of the database will vary by species from place to place. Habitats will be characterized considering direct or indirect exposure to contaminant transport, physical disruption of ecosystem processes, physical disruption of habitat due to site design or operation, and other stresses not related to the site or its constituents (e.g., extreme weather conditions).

The two trophic levels of primary producers and primary consumers will be the main thrust of this assessment (Section 6.2.2.1). The three higher trophic levels (primary producers, primary consumers, and secondary consumers) are composed of wide-ranging species or, in the case of decomposers of specialized organisms, difficult to measure. They will not be studied directly except for microbial biomass. These trophic levels could be a Rocky Flats Plant site-wide study objective.

Populations at risk will be determined by analyzing the distribution of plants and animals within, upgradient, and downgradient of OU No. 2. Potential ecological impacts will be assessed using several lines of evidence which are described in detail in Section 6.2.2. Target or indicator species will be evaluated to determine site-specific constituent impacts.

The risk characterization will provide an evaluation and a summary of all the information that has been collected and present this information in an understandable manner. The risk characterization will also include selection of criteria for organic chemicals, metals, and radionuclides. It will include both a qualitative and a quantitative analysis of risks together with their probability of occurrence (see Section 6.2.4.4). Further, the risk analysis will include an analysis of uncertainties that are intrinsic to the EE process (see Section 6.2.4.5).

This task will also summarize the results of the ecological risk assessment to determine if the objectives were accomplished and if there are uncertainties that have not been resolved.

6 3 5 Task 5 Environmental Evaluation Report

The preparation of the EER will necessitate the accomplishment of three steps or subtasks

- Submittal of a draft EER
- Review and comment by EG&G
- Response to EG&G comments
- Incorporation of responses to comments and submittal of a final EER

The format and content of the EER is addressed in Section 6 4 A suggested EER outline is included in Attachment 4 0

6 3 6 Task 6 Project Management and Documentation

The EE will be a multidisciplinary undertaking staffed by specialists from several different scientific and technical disciplines The project will be managed by a manager who will have primary responsibility for the following functions

- Coordination of all six EE tasks
- Selection and assignment of personnel
- Cost estimating, scheduling, and schedule/cost control
- Tracking of documentation and preparation of the EE report (EER)
- Liaison with EG&G and submittal of progress reports and other documentation
- Coordination with whatever contractors are performing the OU No 2 RFI/RI

The EE staff will include, but not necessarily be limited to, specialists in the following disciplines

- Surface water and ground water hydrology
- Soils science/geology
- Terrestrial ecology
- Aquatic ecology
- Environmental toxicology
- Climatology

- Computer modeling
- Health and safety
- Quality assurance
- Costs/schedule control

Representatives of each of the technical and scientific disciplines will work together as a team to characterize the OU No 2 site and the surrounding area that could possibly be affected by OU No 2 contaminants. The exact geographic scope of the investigation cannot be determined until existing literature has been reviewed and some field work has been undertaken. The scientific and technical team will identify the geographic scope, the location of sources of contamination on or near the site, the types and distribution of ecological habitats, and the nature of possible air, water, sediment, and soil pathways. The details of these investigations are described in the methodology discussion in Section 6.2.

Throughout the EE process, it will be important to coordinate efforts with the RFI/RI process and the health risk assessment for Operable Unit Nos 1, 2, and 5. It will also be necessary to coordinate with contractors responsible for EEs or other types of investigations at OUs in close proximity to OU No 2.

The EE will produce multiple types of documents and documentation requirements. EEWP modifications, progress reports, minutes of meetings with EG&G, field data, photographs, existing reports and other data, records of telephone conferences, scientific literature, sampling and analytical data, and the draft and final EE reports. To the extent practical, all documentation will be retained in the same location for easy access by members of the EE project team and RFI/RI personnel.

6.4 FORMAT AND CONTENT OF THE ENVIRONMENTAL EVALUATION REPORT

The results of the EE will be presented in a clear, concise manner. The conclusions will be organized around the risks posed by contaminants from OU No 2 to specific plant and animal species. Final conclusions will be based on lines of evidence from several assessment techniques. The conclusions section of the EER will include a discussion of the EE objectives to determine if they were accomplished. Also, uncertainties associated with the EE will be presented, along with an evaluation of how these uncertainties influence the conclusions. The EE will determine whether OU No 2 presents an unacceptable environmental risk unless remedial actions are undertaken.

The EER will have three basic uses. It will be used to

- Determine the nature and severity of the environmental risk resulting from existing contamination at OU No. 2 without remedial action (the "no-action" alternative)
- Determine the need for remedial action and provide information needed to evaluate potential environmental impacts of remediation alternatives
- Prepare appropriate environmental documentation needed to comply with the National Environmental Policy Act (NEPA)

The introductory sections in the EER will define the objectives and scope of the EE investigation and generally describe the physical and biological characteristics of the site. Information from this EE and prior studies, such as the OU No. 2 RFI/RI field investigations, will be used to identify the contaminants of concern, assess the sources and fate of transport mechanisms for these contaminants, and describe the logical pathways and receptor species or communities.

The characterization of risks in the EER (see Section 6.2.4) will be based on several lines of scientific evidence. For example, one line of evidence will be based on comparing on-site contaminant concentrations to organic chemical, metal, or radionuclide criteria in addition to toxicity data from the literature. Another line of evidence will compare biological communities at on-site stations to reference stations.

Since the assessment of risk to biological receptors is largely based on the weight of the evidence supporting particular conclusions, a summary section will be included in the EER. This section will present the various lines of evidence supporting (or failing to support) each basic conclusion and will discuss the associated uncertainties. The factors that limit or prevent development of definitive conclusions will be described and the degree of confidence in the data used will be presented.

The EER will be structured and written to facilitate its use by a diverse audience: technical specialists, scientists, administrators, and the general public. Portions involving technical detail, such as explanations of methodologies or fate and transport models, will be presented in appendices. An Executive Summary will be prepared to briefly present the basic information contained in the ecosystem characterization, exposure, toxicity, and risk assessment portions of the report and describe how this information supports the risk characterization conclusions. A glossary will be included to define technical terms along with a list of acronyms. A complete list of references, including the scientific literature cited, will also be included. All of the report elements listed above are included in the OU No. 2 EER outline in Attachment 4.0.

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section provides a preliminary identification of chemical-specific ARARs for alluvial (upper HSU) ground water, and soils at OU No 2 so that appropriate analytical detection limits are used during the RFI/RI. Use of appropriate detection limits is necessary to allow evaluation of compliance with ARARs in the CMS/FS report. As described in Section 7.2, evaluation and establishment of location-specific ARARs are a part of the RI process and will be addressed in the RFI/RI Report. Final chemical-specific ARAR determinations will also be addressed in the RFI/RI Report. Identification of action-specific ARARs and remediation goals is a part of the feasibility study process and will be addressed in the CMS/FS Report.

7.1 THE ARAR BASIS

The basis for ARARs is cited in Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), which requires that Fund-financed, enforcement, and federal facility remedial actions comply with all applicable or relevant and appropriate federal environmental or promulgated state environmental or facility siting laws. For the purposes of identification and notification of promulgated state standards, the term "promulgated" means that the standards are of general applicability and are legally enforceable [NCP, 40 Code of Federal Regulations (CFR) 300.400(g)(4)].

Health-based, chemical-specific ARARs pertinent to ground water and soils (environmental media addressed by this work plan) have been identified for the EPA CLP, TCL organic, and TAL inorganic compounds, as well as radionuclides and conventional pollutants, that were detected above background. The chemical-specific ARARs are derived primarily from federal and state health and environmental statutes and regulations. As discussed below, in some instances these standards are classified as items "to be considered" (TBC). A summary of chemical-specific ARARs for the contaminants found at the 903 Pad, Mound, and East Trenches Areas in alluvial ground water is presented in Table 7-1. Maximum contaminant concentrations identified in the respective media at OU No 2 are shown in the table for comparison to the ARAR or TBC. These ARARs pertain to both the upper and lower HSUs (alluvial and bedrock ground water), due to the potential hydraulic interconnection of the two units. The same list of parameters will be utilized for analysis of samples collected from ground water in both the alluvial and bedrock OU No 2 RFI/RI work plans. In the final chemical-specific ARAR analysis, a common list of parameters will be analyzed for both HSUs.

One medium for which chemical-specific ARARs do not currently exist is soils. As the remedial investigation proceeds, information will become available from the baseline risk assessment which will allow a determination of acceptable contaminant concentrations in soils to ensure environmental "protectiveness." This is discussed further in Section 7.5.

TABLE

PROPOSED CHEMICAL SPECIFIC ABARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water ^a (µg/l)	Well Designation # & Sample Date	Detection Limit (µg/l)	Proposed ABAR (µg/l)	Proposed TBC (µg/l)	Reference	Comment
<u>Organic Compounds</u>							
Acetone	13008	1587 (10/07/87)	10		100	Parameter is RCRA (40 CFR Part 261) Appendix IX constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC	
Methylene Chloride	240JB	1587 (10/07/87)	5		50	Parameter is RCRA (40 CFR Part 261) Appendix VIII constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC	
Tetrachloroethene	528000	0174 (05/22/87)	5		5	SDWA MCL (40 CFR 141.61(a)) is TBC *	
Toluene	53	36878R (11/05/87)	5		1000	SDWA MCL (40 CFR 141.61(a)) is TBC *	Maximum detected concentration is below proposed TBC standard
Trichloroethene	221860	36878R (05/04/88)	5	5		SDWA MCL (40 CFR 141.61(a))	
Carbon Disulfide	4JA	0174 (01/03/89)	5		50	Parameter is RCRA (40 CFR Part 261) Appendix VIII constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC	Maximum detected concentration is below proposed TBC standard
Chloroform	5427	36878R (11/05/87)	5	100		SDWA MCL (40 CFR 141.12)	Standard is for total trihalomethanes
Vinyl Chloride	930	3586 (01/03/89)	10	2		SDWA MCL (40 CFR 141.61(a))	
Carbon Tetrachloride	4835	4286 (09/03/87)	5	5		SDWA MCL (40 CFR 141.61(a))	

TABLE 7- (continued)

PROPOSED CHEMICAL SPECIFIC ABARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (µg/l)	Well Designation # & Sample Date	Detection Limit (µg/l)	Proposed ABAR (µg/l)	Proposed TBC (µg/l)	Reference	Comment
Organic Compounds (cont.)							
1,1 Dichloroethane	62A	3586 (01/03/89)	5		5U	Parameter is RCRA (40 CFR Part 261) Appendix IX constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC	
1,2 Dichloroethane	400	0171 (05/21/87)	5	5		SDWA MCL [40 CFR 141.61(a)]	
1,1 Dichloroethene	1044	3687BR (11/05/87)	5	7		SDWA MCL [40 CFR 141.61 (a)]	
1,2-Dichloroethene (total)	1600	3586 (03/17/87)	5		5U (70)	Parameter is RCRA (40 CFR Part 261) Appendix VIII constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC SDWA MCL, in parentheses, [40 CFR 141.61(a)] is also TBC *	
1,1,1 Trichloroethane	2892	0171 (07/02/87)	5	200		SDWA MCL [40 CFR 141.61(a)]	
1,1,2-Trichloroethane	51	0271 (02/25/88)	5		28	WQCC Groundwater, Interim Organic Pollutant Standard is TBC	
4-Methyl 2-pentanone	35	3287 (03/09/88)	10		10U	Parameter is RCRA (40 CFR Part 264) Appendix IX constituent. RCRA 40 CFR Part 264 Subpart F (background) is TBC	
2 Hexanone	975	3687BR (03/09/88)	10		10U	Parameter is RCRA (40 CFR Part 264) Appendix IX constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC	

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ADARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (µg/l)	Well Designation # & Sample Date	Detection Limit (µg/l)	Proposed ADAR (µg/l)	Proposed TBC (µg/l)	Reference	Comment
Organic Compounds (cont.)							
Styrene	9A	0174 (01/03/89)	5		5U (100)	Parameter is RCRA (40 CFR Part 264) Appendix IX constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC SDWA MCL, in parentheses [40 CFR 141.61(a)] is TBC *	
Xylene (total)	4J	3986 (03/09/88)	5		5U (10,000)	Parameter is RCRA (40 CFR Part 264) Appendix IX constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC SDWA MCL, in parentheses [40 CFR 141.61(a)] is TBC *	
Ethyl Benzene	3J	3986 (03/09/88)	5		680 (700)	Parameter is RCRA (40 CFR Part 264) Appendix IX constituent RCRA 40 CFR Part 264 Subpart F (background) is TBC SDWA MCL, in parentheses [40 CFR 141.61(a)] is TBC *	
Benzene	2JA	0271 (10/31/88)	5	5		SDWA MCL [40 CFR 141.61(a)]	

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (mg/l)	Well Designation # & Sample Date	Detection Limit (mg/l)	Proposed ARAR (mg/l)	Proposed TBC (mg/l)	Reference	Comment
<u>Dissolved Metals</u>							
Aluminum	2 6796	2587BR (10/21/87)	0 20		5 0	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	Maximum detected concentration is below proposed standard
Antimony	0 1177	2987 (08/08/88)	0 06		0 06U	RCRA (40 CFR Part 264 94) Subpart F (Background) is TBC	
Arsenic	0 004J	3586 (03/02/88)	0 01	0 05		SDWA MCL [40 CFR 141 11 (b)]	Maximum detected concentration is below proposed standard
Barium	0 932I	1487BR (08/31/87)	0 20	1 0		SDWA MCL [40 CFR 141 11(b)]	Maximum detected concentration is below proposed standard
Beryllium	0 004J	4186 (10/22/87)	0 005		0 1	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	Maximum detected concentration is below proposed standard
Cadmium	0 009A	6286 (06/10/89)	0 005	0 01	0 005	SDWA MCL [40 CFR 141 11(b)]. SDWA MCL [40 CFR 141 62(b)] is TBC *	Maximum detected concentration is below proposed standard
Calcium	408 4416	1487BR (08/31/87)	5	NS		No Standard	
Chromium	0 1223	0374 (10/22/87)	0 01	0 05	0 0	SDWA MCL [40 CFR 141 11(b)] SDWA MCL [40 CFR 141 62(b)] is TBC *	Analytical results are for total chromium
Copper	0 8355	2987 (08/08/88)	0 025		0 2	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	Maximum detected concentration is below proposed standard
Iron	4 347	2587BR (10/21/87)	0 1		0 3	Potential* WQCC Ground Water Standard, Table 2, Secondary Drinking Water Standard is TBC	Analytical results are for soluble iron

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ARARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (mg/l)	Well Designation # & Sample Date	Detection Limit (mg/l)	Proposed ARAR (mg/l)	Proposed TBC (mg/l)	Reference	Comment
<u>Dissolved Metals</u> (cont.)							
Lead	0.024	6586 (05/28/87)	0.005	0.05		SDWA MCL [40 CFR 141.11(b)]	Maximum detected concentration is below proposed standard
Lithium	0.16	2987 (02/29/88)	0.1		2.5	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	Maximum detected concentration is below proposed standard
Magnesium	135.7122	2987 (02/29/88)	5	NS		No Standard	
Manganese	4.3699	3586 (05/03/89)	0.015		0.05	Potential* WQCC Ground Water Standard, Table 2, Secondary Drinking Water Standard is TBC	Analytical results are for soluble manganese
Mercury	0.013	4286 (07/23/87)	0.0002	0.002		SDWA MCL [40 CFR 141.11(b)]	Maximum detected concentration is below proposed standard
Molybdenum	0.0808	2987 (04/21/88)	0.008	NS		No Standard	
Nickel	1.4097	2987 (04/21/88)	0.04		0.2	Potential* WQCC Ground Water Standard; Table 3, Agricultural Standard is TBC	Maximum detected concentration is below proposed standard
Potassium	31.0	1487 (08/31/87)	5	NS		No Standard	
Selenium	0.450	2987 (02/01/89)	0.005	0.01		MCL [40 CFR 141.11(b)]	
Silver	0.128	4286 (05/04/88)	0.01	0.05		MCL [40 CFR 141.11(b)]	
Sodium	405.0172	2987 (04/21/88)	5	NS		No Standard	

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ABARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (mg/l)	Well Designation # & Sample Date	Detection Limit (mg/l)	Proposed ABAR (mg/l)	Proposed TBC (mg/l)	Reference	Comment
Dissolved Metals (cont.)							
Strontium	7 7076	14878R (08/31/87)	0 2	NS		No Standard	Background is 7 12 mg/l
Thallium	0 01	2387 (09/10/87)	0 01		0 01U	RCRA (40 CFR Part 264 94) Subpart F (Background) is TBC	Maximum detected concentration is below proposed standard.
Vanadium	0 0401	25878R (10/21/87)	0 05		0 1	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	
Zinc	2 7735	2987 (08/08/88)	0 02		2 0	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	Maximum detected concentration is below proposed standard

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ADARs
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (mg/l)	Well Designation # & Sample Date	Detection Limit (mg/l)	Proposed ADAR (mg/l)	Proposed TBC (mg/l)	Reference	Comment
<u>Non Metallic Inorganics</u>							
pH (min)	7.2	6686 (06/02/89)	0.1		6.5	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	Minimum pH value is within proposed standard
pH (max)	8.7	6286 (06/10/89)	0.1		8.5	Potential* WQCC Ground Water Standard, Table 3, Agricultural Standard is TBC	
Nitrite	15.45	3287 (10/26/87)	1.0		1.0	Potential* WQCC Ground Water Standard, Table 1, Human Health Standard is TBC	Analytical results are total nitrite plus nitrate as nitrogen. Reanalysis is required to determine if proposed nitrite standard is exceeded.
Nitrate	15.45	3287 (10/26/87)	5	10.0		SDWA MCL [40 CFR 141.11 (b)]	Analytical results are total nitrite plus nitrate as nitrogen. Results indicate that proposed nitrate standard is not exceeded.
Chloride	947	4186 (12/16/87)	5			Potential* WQCC Ground Water Standard, Table 2, Secondary Drinking Water Standard is TBC	
Sulfate	1157	2987 (04/21/88)	5		250	Potential* WQCC Ground Water Standard, Table 2, Secondary Drinking Water Standard is TBC	

TABLE 7-1 (Contd)

PROPOSED CHEMICAL SPECIFIC ARARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU 2 Area Alluvial Ground Water* (mg/l)	Well Designation n # & Sample Date	Detection Limit (mg/l)	Proposed ARAR (mg/l)	Proposed TBC (mg/l)	Reference	Comment
<u>Non Metallic Inorganics (cont.)</u> Bicarbonate	642	3586 (03/17/87)	10	NS		No Standard	
TDS	3219	2987 (02/29/88)	5		1643	Potential* WQCC Ground Water Standard, Table 4, Standard is TBC	Proposed standard is calculated from the upper tolerance interval in background wells Value includes 95% of the population at 95% confidence multiplied by 1.25

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentrations In OU2 Area Ground Water" (pCi/l)	Well Designation # & Sample Date	Detection Limit (pCi/l)	Proposed ARAR (pCi/l)	Proposed TBC (pCi/l)	Reference	Comment
<u>Radionuclides</u>							
Gross Alpha	250 ± 52	0374 (10/22/87)	2	15		SDWA MCL [40 CFR 141.15 (b)]	
Gross Beta	327 ± 20	0374 (10/22/87)	4	4 (mrem)		SDWA MCL [40 CFR 141.16 (b)]	
^{210}Po	0.6 ± 0.71	6286 (07/06/87)	0.01		15	WQCC Statewide Standard for Radionuclide Materials in Ground Water is TBC	Maximum detected concentration is below proposed standard. Concentration is estimated below minimum detectable limit (MDL)
Am^{241}	0.831 ± 0.148	1587 (09/11/87)	0.01		0.05	WQCC Surface Water Standard is TBC	
H^3	560 ± 290	4286 (10/14/87)	400	20000		SDWA MCL [40 CFR 141.16 (b)]	Maximum detected concentration is below proposed standard
Cs^{137}	0.3 ± 0.5	6286 (06/10/89)	1	NS		No Standard	Concentration is estimated below MDL
Ra^{226}	0.7 ± 0.3	6586 (06/01/89)	0.5	5		SDWA MCL [40 CFR 141.15 (a)]	Standard is for Ra^{226} and Ra^{228} . Maximum detected concentration is proposed standard. Concentration is estimated below MDL
Sr^{90}	5.0	0174 (07/23/87)	1	8		SDWA MCL [40 CFR 141.16 (b)]	Standard is for Ra^{226} and Ra^{228} . Maximum detected concentration is below proposed standard. Concentration is estimated below MDL
U^{238}	63.7 ± 5.3	12878R (02/25/88)	1.8		5	CDM Surface Water Standard is TBC	

TABLE 7-1 (continued)

PROPOSED CHEMICAL SPECIFIC ABARS
FOR COMPOUNDS AND ELEMENTS DETECTED ABOVE BACKGROUND IN
ALLUVIAL GROUND WATER AT THE 903 PAD, MOUND, AND EAST TRENCHES

a	-	Maximum compound concentrations determined from data collected through the second quarter of 1989
b	-	
B	-	Compound also present in blank
J	-	Estimated below detection limit
U	-	Detection limit
*	-	WQCC Groundwater Standards - Table 1 Human Health Standards, Table 2 Secondary Drinking Water Standards, Table 3 Agricultural Standards, effective October 30, 1990, are potential TBC standards since final groundwater classification of RFP has not been completed

ARARs addressing contaminants in air will be included in the CMS/FS Report. In general, federal and state standards for air exist only as source- or activity-specific requirements and, accordingly, will be addressed in detail in the FS process.

Surface water stations in the streams, ponds, and ditches in the OU No. 2 study area are considered to be part of OU Nos. 5 and 6. Seeps, however, are considered part of OU No. 2 as they represent ground-water discharge locations. These seeps, therefore, are treated as points at which to evaluate ground water quality for the purposes of this work plan. Accordingly, no discussion of ARARs relative to surface water is presented in the section. Ground-water seeps, their impact on surface waters, streams, and compliance with surface water ARARs is a subject of the OU Nos. 5 and 6 RFI/RI work plans.

7.2 THE ARAR PROCESS

7.2.1 ARARs

"Applicable requirements," as defined in 40 CFR 300.5, are "those clean-up standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be "applicable." "Relevant and appropriate requirements," also defined in 40 CFR 300.5, are "those clean-up standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws, that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate." The most stringent promulgated standards are applied as ARAR (Preamble to NCP, 55 FR 8741).

7.2.2 TBCs

In addition to applicable or relevant and appropriate requirements, advisories, criteria, or guidance may be identified TBC for a particular release. As defined in 40 CFR 300.400(g)(3), the TBC category consists of advisories, criteria, or guidance developed by EPA, other federal agencies, or states that may be useful in developing remedies. Use of TBCs is discretionary rather than mandatory, as opposed to the use of ARARs, which is mandatory.

7 2 3 ARAR Categories

In general, there are three categories of ARARs. These categories are

- 1 Ambient or chemical-specific requirements
- 2 Location-specific requirements
- 3 Performance, design, or other action-specific requirements

ARARs are generally considered to be dynamic in nature in that they evolve from general to very specific in the CERCLA site clean-up process. Initially, during the RI work plan stage, probable chemical-specific ARARs may be identified, usually based on a limited amount of data. Chemical-specific ARARs at this point have meaning only in that they may be used to establish appropriate detection limits, so that data collected in the RI will be amenable for comparison to ARAR standards. These proposed chemical-specific ARARs are not necessarily representative of the final ARARs which will ultimately control selected remedial actions. It is also appropriate to identify location-specific ARARs early in the RI process so that information may be gathered to determine if restrictions have been placed on the concentration of hazardous substances or on the conduct of an activity solely because it occurs in a special location.

7 2 4 Feasibility Study ARAR Requirements

Development of a preliminary list of potential chemical-specific ARARs in the RI process also allows the establishment of a list of preliminary remediation goals in the early FS process, which is essentially a tentative listing of contaminants together with initially anticipated clean-up concentrations or risk levels for each medium. Preliminary remediation goals serve to focus the development of alternatives on remedial technologies that can achieve the remediation goals, thereby limiting the number of alternatives to be considered in the detailed remedial alternative analysis, conducted later in the FS process. As more information becomes available during the RI stage, chemical-specific ARARs may become more refined as constituents are added or deleted. Once data collection is complete, revised chemical-specific ARARs may be proposed.

When the data collection is complete, it is also appropriate to refine location-specific ARARs which may affect the development of remedial alternatives. In addition, during development of remedial action alternatives at the beginning of the FS process, a preliminary consideration of action-specific ARARs will be conducted. As remedial alternatives are screened during the FS, action-specific ARARs will be identified. When a detailed analysis of the remedial alternatives is conducted, all action-specific ARARs are refined and finalized with respect to each alternative before a comparison of alternatives begins. At this point, a discussion is provided in the FS report for each remedial alternative regarding the rationale for all ARAR determinations.

7.3 REMEDIAL ACTION AND REMEDIATION GOALS

CERCLA §121 specifically requires attainment of all ARARs. Moreover, as explained in the preamble to the NCP (55 FR 8741), in order to attain all ARARs, a remedial action must comply with the most stringent requirement, which then ensures attainment of all other ARARs. Furthermore, CERCLA requires that the remedies selected must attain ARARs and be protective of human health and the environment. Consequently, preliminary remediation goals based on ARARs will require modification as new information and data are collected in the RI, including the baseline risk assessment (to be conducted), when ARARs are not available or are determined to be inadequate for protection of human health and the environment.

Development of remediation goals is actually a portion of the overall development of remedial action objectives, which ultimately will define the required endpoint of the selected remedial action. As stated in the preamble to the NCP (55 FR 8713), "remedial action objectives are the more general description of what the remedial action will accomplish. Remediation goals are a subset of remedial action objectives and consist of medium-specific or operable unit-specific chemical concentrations that are protective of human health and the environment and serve as goals for the remedial action. The remedial action objectives should specify (1) the contaminants of concern, (2) exposure routes and receptors, and (3) an acceptable contaminant level or range of levels for each exposure medium (i.e., a preliminary remediation goal)." According to 40 CFR 300.430 (e)(2)(i) "Remediation goals shall establish acceptable exposure levels that are protective of human health and the environment and shall be developed by considering the following"

- (A) ARARs (chemical-specific) and
 - (1) Acceptable exposure levels for systemic toxicants,
 - (2) Acceptable exposure levels for known or suspected carcinogens,
 - (3) Technical limitations (e.g., detection limits),
 - (4) Uncertainty factors, and
 - (5) Other pertinent information
- (B) Maximum Contaminant Level Goals (MCLGs) [or Maximum Contaminant Levels (MCLs) where MCLGs are zero or where MCLGs are not relevant and appropriate], where relevant and appropriate
- (C) Acceptable exposure levels where multiple contaminants or multiple exposure pathways will cause exposure at ARAR levels resulting in cumulative risk in excess of 10^{-4}
- (D) CWA Ambient Water Quality Criteria (AWQC), where relevant and appropriate
- (E) A CERCLA Alternative Concentration Limit (ACL) established pursuant to CERCLA § 121(d)(2)(B)(ii)
- (F) Environmental evaluations performed to assess specific threats to the environment

Once a preferred remedial action alternative is formally selected, all chemical-, location-, and action-specific ARARs have also been defined in final form. If it is found that the most suitable remedial alternative does not meet an ARAR, the NCP at 40 CFR 300.430 (f)(1)(ii)(C) provides for waivers of ARARs under certain circumstances, such as technical impracticability, risk, or inconsistent application of state requirements. From this point, the alternative will become the final remedy as it is incorporated into the Record of Decision (ROD). Once the final ROD has been signed, requirements may be modified only when they are determined to be applicable or relevant and appropriate and necessary to ensure that the remedy is protective of human health and the environment [40 CFR 300.430(f)(1)(ii)]

7.4 OU No. 2 ALLUVIAL GROUND-WATER ARARs

The ARARs for alluvial ground water listed in Table 7-1 were developed using the ARARs rationale described above and were identified by examining the following promulgated standards:

- SDWA MCLs
- RCRA 40 CFR Part 264 Subpart F concentration limits

7.4.1 Safe Drinking Water Act MCLs

SDWA MCLs represent the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system [40 CFR 141.2(c)]. Because ground water at OU No. 2 is a potential source of drinking water, MCLs are ARARs. Furthermore, the NCP [40 CFR 300.430 (e)] requires that, in development of alternatives for final remediation, the following be considered for current or potential sources of drinking water: attainment of MCLGs or MCLs, if MCLGs are zero, and attainment of CWA AWQC where relevant and appropriate. Because ground water at OU No. 2 is a potential source of drinking water, the MCLGs (or MCLs) are relevant and appropriate and should be attained (note: the MCLGs are currently zero or equal to the MCLs). It should be noted that on January 30, 1991 (56 FR 3526) EPA published new MCLs and MCLGs in final form for a number of the constituents identified in Table 7-1. These standards are effective July 30, 1992, and will be regarded as relevant and appropriate at that time. For purposes of this work plan, the new MCLs (new MCLGs are zero or equal to the MCLs) have been determined to be proposed TBC and are identified as such in Table 7-1. The AWQC, are not ARARs and are not considered with respect to ground water, since they are intended for the protection of surface water relative to fish ingestion and drinking water, or only fish ingestion. Therefore, it is inappropriate to apply such CWA criteria to ground water.

7 4 2 RCRA 40 CFR Part 264 Subpart F Concentration Limits

Owners or operators of facilities that treat, store, or dispose of hazardous waste must ensure that hazardous constituents listed in 6 CCR (Colorado Code of Regulations) 1007-3 and 40 CFR 261 Appendix VIII entering the ground water from a regulated unit do not exceed concentration limits (6 CCR 1007-3 and 40 CFR 264 94) at the point of compliance in the uppermost aquifer. The concentration limits include standards for 14 compounds (these standards are equivalent to and a subset of SDWA MCLs and are identified at 40 CFR 264 94, Table 1), with background or ACLs used as the standards for the other RCRA 40 CFR Part 261 Appendix VIII constituents or 40 CFR Part 264 Appendix IX constituents. These concentration limits apply to RCRA "regulated units" subject to permitting (defined at 40 CFR 264 90 to include landfills, surface impoundments, waste piles, and land treatment units) that received RCRA hazardous waste after July 26, 1982. Although OU No. 2 does not contain RCRA-regulated hazardous waste management units, it does contain IHSSs. As a result, these RCRA 40 CFR Part 264 Subpart F regulations are considered relevant and appropriate for ground water.

As discussed above, an ACL may be established for a hazardous constituent if it is determined that attainment of a Subpart F Table 1 constituent standard or background standard is not necessary to ensure adequate protection of human health and the environment. Furthermore, EPA has stated that for potential drinking water sources, the Agency's preference is to set remediation levels that are the equivalent of exposure- or health-based ACLs under RCRA (EPA, 1988d). Therefore, it is inappropriate to establish background as an ARAR unless it may be determined through risk assessment that attainment of background is necessary for adequate protection of human health and the environment. Accordingly, 40 CFR Part 264 Subpart F Table 1 standards and hazardous constituent background values will be applied as TBC until such time as risk assessment information indicates some other alternative standard is necessary to ensure "protectiveness." TBC background ground-water values for Subpart F are applied using maximum concentrations from background ground water in both the alluvial and bedrock lithologies at Rocky Flats Plant.

7 4 3 Ground-Water TBCs

The Colorado Water Quality Control Commission (WQCC) state-wide ground-water standards have been applied as TBC since they are not yet enforceable. Similarly, since ground water at Rocky Flats Plant has not been classified, the use-specific standards in Tables 1 through 4 of the WQCC Basic Standards for Ground Water at 3 11 0 (5 CCR 1002-8) have also been applied as TBC where ARARs are not available. In this application, the most stringent of the standards in Tables 1 through 4 has been identified as TBC.

7 5 OPERABLE UNIT NO 2 SOIL ARARs

As discussed in Section 7 1, one medium for which chemical-specific ARARs do not currently exist is soils, however, a risk assessment will be performed to determine acceptable contaminant concentrations in soils to ensure environmental "protectiveness ". At this time, with respect to establishing analytical detection limits for soils, use of the method detection limits provided in the GRRASP (EG&G, 1990k), which are CLP contract required quantitation limits, should enable meaningful interpretation of soil sample results

7 6 OU NO 2 ARARs SUMMARY

Table 7-1 shows that certain volatile organics, metals, and major ions that were analyzed have exceeded proposed chemical-specific ARARs at some locations within OU No 2. This does not indicate releases of these constituents are occurring, since the concentrations of some substances may be due to past releases or to natural geochemical processes. The listing of Table 7-1 has been presented to identify parameters for which analysis should be conducted in the Phase II RFI/RI, and to identify the minimum acceptable detection limits for analytes found in OU No 2 alluvial ground water. The FS will evaluate technologies that address these constituents.

Of the elements/compounds detected in ground water at OU No 2, there are no ARARs or TBCs for calcium, magnesium, molybdenum, potassium, sodium, or strontium. However, the TDS TBC provided by the WQCC Ground Water Standards establishes the acceptable aggregate concentration for the major metal ions (excludes strontium and molybdenum).

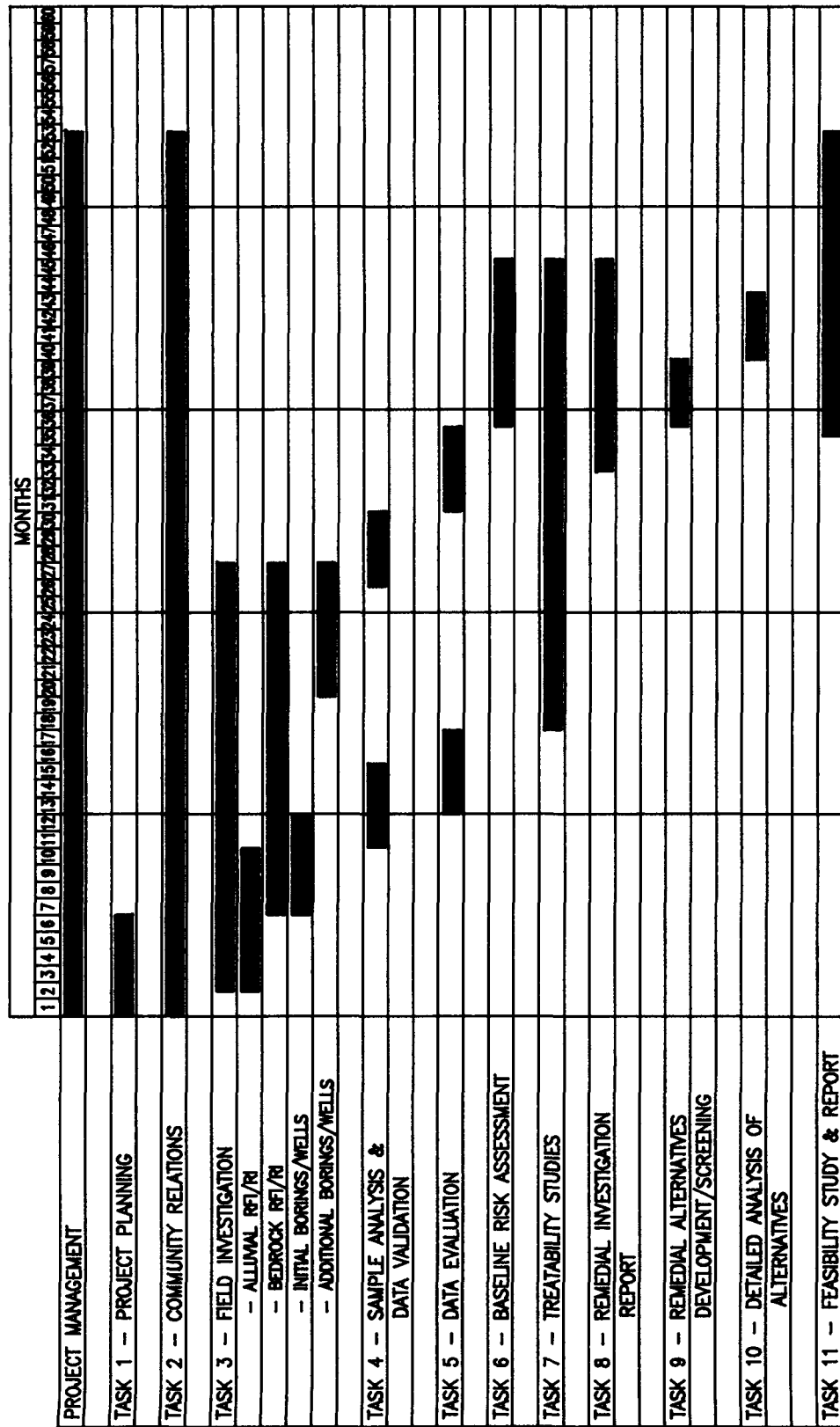
For any contaminants detected in ground water for which no ARARs or TBCs were found, analytical detection limits will be based on the method detection limits provided in the GRRASP (EG&G, 1990k), which are CLP contract required quantitation limits and should enable meaningful interpretation of sample results. Risk-based concentrations based on the baseline risk assessment establish the remediation goals for these trace metals and organics, thus ensuring environmental "protectiveness ".

SCHEDULE

The schedule for conducting the Phase II RFI/RIFS is summarized in Figure 8-1. The schedule includes both the alluvial and bedrock components of the RFI/RI and the CMS/FS activities. The time frames are in accordance with the IAG schedule.

As discussed in Section 5.0 (FSP), the RFI/RI for the alluvial characterization will be conducted in steps. Monitoring wells will be installed for plume characterization followed by the drilling and installation of borings and monitoring wells for source characterization. Borehole, ground-water, sediment, and surficial soil samples will be collected for chemical analysis. The data will be validated and evaluated for incorporation into the draft and final RFI/RI reports.

During RFI/RI report preparation, treatability studies will be in progress and the CMS/FS will begin. The CMS/FS will include remedial alternatives development and screening, and detailed analysis of alternatives. According to this schedule, nearly four years will elapse from the time this work plan is finalized until the final CMS/FS report is prepared.



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

PROPOSED PHASE II RFI/RI SCHEDULE

FIGURE 8-1

February, 1991

SECTION 9.0
QUALITY ASSURANCE ADDENDUM (QAA)

The QAA for OU No 2 and the QAPP will be submitted to EPA and CDH as controlled documents under separate cover. These documents will establish specific QA controls applicable to the field investigations for OU No 2.

The following items will be presented in the QAA:

- ER Program organization and responsibilities
- Data quality objectives
- Analytical methods and detection limits for the FSP parameters
- EG&G SOPs applicable to the field activities
- Data reduction, validation, and reporting requirements and guidelines
- Document control specifications
- Information on sample containers, preservation, and holding times
- Chain-of-custody protocol
- Control of measuring and testing equipment
- Handling, storage, and shipping of samples
- Recordkeeping

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GLOSSARY OF ACRONYMS

AEC	U S Atomic Energy
CDH	Colorado Department of Health
cm	centimeter
CSU	Colorado State University
EM	Energy Measurements
HClO ₄	Perchloric acid
HF	Hydrofluoric acid
HPGe	High Purity Germanium Gamma Detectors
IHSS	Individual Hazardous Substance Site
g	gram
km	kilometers
kPa	kiloPascals
ℓ	liter
m	meter
M	Molar
mℓ	milliliter
mph	miles per hour
nm	nanometer
OU	Operable Unit
pCi/ℓ	picoCuries per liter
pCi/g	picoCuries per gram
RFP	Rocky Flats Plant
rpm	revolutions per minure
TDR	Time Domain Reflectometry
μm	micrometer

1 1 STATEMENT OF THE PROBLEM

The contamination of surficial soils around Rocky Flats Plant by plutonium (Pu) oxides was mainly caused by leaking barrels of plutonium-contaminated oil in the area known as the 903 Pad (Krey and Hardy, 1970). Numerous studies (Krey and Hardy, 1970, Seed, et al, 1971, Poet and Martell, 1972, Johnson, et al, 1976, Little, 1980, Little, et al, 1980) concluded that surficial soils in the area east of the 903 Pad are contaminated with plutonium and americium (Am) due to wind dispersal of soil particles during cleanup operations. More recently, the Phase I RI for Operable Unit Number 2 (OU No. 2) (Rockwell International, 1987a) found that the concentrations of plutonium and americium were elevated in composite soil samples adjacent to Trench T-2 (BH25-87, BH 26-87, and BH27-87) and the Reactive Metal Destruction Site (BH28-87) T-1 (boreholes BH35-87 and BH36-87). In addition, the Phase I RI found occasional elevated concentrations of plutonium [> 0.05 pCi/l] in filtered surface water samples from seeps (surface water sampling stations SW-50, SW-53, and SW-54) and in stream sediments [> 0.9 pCi/g] along Woman Creek (sediment sampling stations SED-25, SED-26, SED-29, and SED-30). It has been suggested that the source of the contaminated sediments is the surface soils from the 903 Pad area which are transported by wind. However, the elevated concentrations of plutonium in filtered and unfiltered seep waters above Woman Creek suggest that some of the plutonium may travel in surface and ground water. Also, soil sampling results indicate that the actinides are enriched near the soil surface. Further investigation is necessary to characterize the transport mechanisms that control the spatial and vertical distribution of these radionuclides.

1 2 OBJECTIVES

The objectives of the proposed work plan for the surficial soils are to determine the spatial and vertical extent of plutonium and americium in surficial soils of the remedial investigation areas and in the buffer zone, to study the physicochemical association of plutonium and americium in surficial soils (static and mobile soil phases) above seeps SW-50, SW-53, and SW-54, to study the movement of both water and radionuclides (colloidal and dissolved) down the soil column, and to ascertain the hydrogeochemical relationships between the soil interstitial water and the seeps downslope.

1 3 SPATIAL DISTRIBUTION OF PLUTONIUM AND AMERICIUM EAST OF THE ROCKY FLATS PLANT

1 3 1 Geostatistical Kriging Approach

The spatial dependency and distribution of actinides in surficial soils will be studied through the use of geostatistical techniques. The key concept of geostatistics is the regionalized variable. The variable is a function describing the geographical distribution of an environmental contaminant, such as plutonium and americium, in the soil environment. A principal concern of geostatistics is to relate the results obtained from one method to that obtained from another method [i.e., Rocky Flats Plant (RFP) as compared to the Colorado Department of Health (CDH) soil sampling techniques]. These characteristics of geostatistics will allow the use of historical data together with results generated by Phase II. For example, the spatial distribution of plutonium and americium in the soils collected using the Rocky Flats Plant method [Seed, et al., 1971, unpublished data collected 1975 through 1978, and annual soil sampling conducted at Rocky Flats Plant (Rockwell International, 1975 through 1985, 1986, 1987b, 1989 and EG&G, 1990a)], as well as aerial and surface radiological surveys conducted by EG&G/Energy Measurements (EM) in 1981 and 1989 (EG&G/EM, 1982 and 1990, respectively).

Kriging will be used to make spatial distribution (contour) maps. Unlike conventional contouring subroutines, kriging uses certain statistical optimal properties and provides measures of the error of the contoured surface. Kriging uses the information from the semivariogram to find an optimal set of weights that are used in the estimation of the surface at unsampled locations. The semivariogram describes the rate of change in a regionalized variable and measures the degree of spatial dependence between samples within geographical boundaries. The variogram splits the total variance in a data set into two parts. The first represents the spatial differences between the values of the samples taken at points separated by increasingly large distances, whereas the second represents local or short-range variances. The latter is called the nugget variance which represents random variance. Because the semivariogram is a function of distance the weights change according to the geographical arrangement of the samples (Isaaks and Srivastava, 1989).

The need for better understanding of the spatial and vertical distribution of plutonium were recognized many years ago by the Committee Evaluation of Plutonium Levels in Soils within and surrounding a U.S. Atomic Energy Commission (AEC) Installation at Rocky Flats, Colorado (Seed, et al., 1971). They recommended that the mechanism of plutonium transport in soil be addressed, and the chemical form of plutonium in Rocky Flats Plant soils should be determined. In response to these recommendations both extensive and intensive studies were conducted.

The plutonium concentrations in soils east of the 903 Pad clearly suggest a spatial trend from west to east (Figure 1-1). The strong west-east vector suggests that wind is the most probable force that controlled plutonium transport across the landscape.

Experimental semi-variograms consist of three parameters sill, range, and nugget. The sill is defined as the maximum value in the semi-variogram where $\gamma(h) = C$ for $h \geq a$. The value $h = a$ is called the range and is the maximum separation distance for which sample pairs remain correlated. In most soil studies $\gamma(h)$ will remain nonzero as h approaches zero, which is called the nugget effect ($\gamma(h) = C_0$, $h > 0$). It reflects the inherent random variation of a contaminant dispersion in the environment that cannot be predicted by any method and/or variability between sampling points at a distance less than that actually used or available. The variogram computation suggests a gaussian model with nugget of 0.34, sill of 0.71 and a range parameter of 1,237 (Figure 1-2). The gaussian model was computed using the following formula:

$$\gamma(h) = C_0 + C[1 - \exp(-h^2/A_0^2)]$$

where

$\gamma(h)$ = variogram,

h = lag interval,

C_0 = nugget variance,

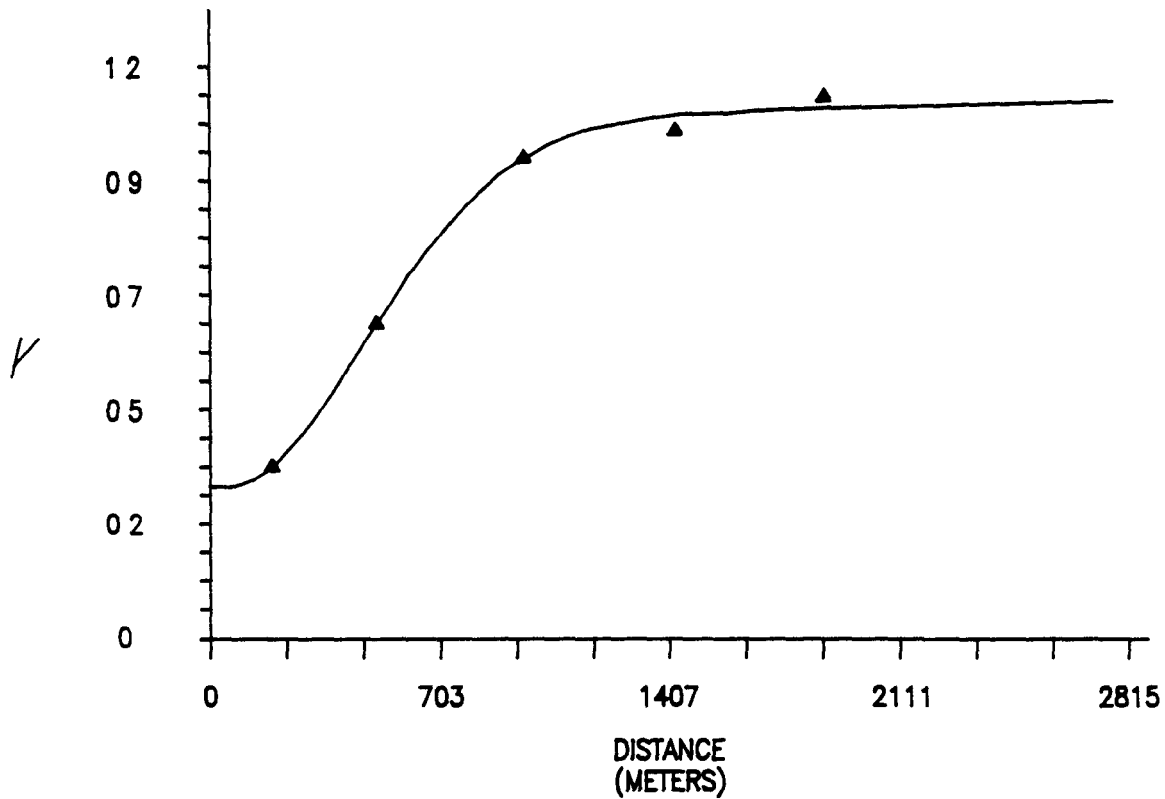
C = sill, and

A_0 = range parameter

Kriging estimates using the gaussian model were computed for the extensive study sites and are depicted in Figures 1-1 and 1-3. Figure 1-1 depicts contours of soil-plutonium estimates in the buffer zone east of the 903 Pad. Kriging permits one to estimate the variance of each estimated mean and hence to assess whether additional data are needed in a given area. The main sources of the error estimates are (1) number of the nearby samples, (2) proximity of the available samples, (3) spatial arrangement, and (4) the nature of the contaminant. Figure 1-3 illustrates the kriging standard of error estimates, which are low in the center of the buffer zone, and which verify the goodness-of-fit of the kriging estimates in this location. However, large standard error estimates were observed near the 903 Pad and in the northeast and southwest corners of the grid (Figure 1-3). These findings strongly suggest that a larger data set is needed in order to better estimate the spatial distribution of plutonium east of the 903 Pad. It should be noted, however, that on numerous occasions soils east of the 903 Pad were collected for various reasons (e.g., EG&G/EM, 1990). The unpublished data collected in 1975 to 1978 was used in the above kriging computation because of its inherent consistency (sampling, handling, and analysis of the soils, and excellent geographic distribution of the soils).

The traditional method of mapping (hand-contouring or computer generated contour maps) usually produces smooth contours that honor the data at known points. These techniques usually produce fairly erratic contours. Geostatistical techniques will produce a much smoother map that shows the general trend of a given pollutant (e.g., Figure 1-1). In addition, kriging will provide an estimate of the errors of estimation for the general trend (Figure 1-3) as well as the correlation between sample values at the sampling interval used. A

ISOTROPIC SEMIVARIOGRAM GAUSSIAN MODEL



THE VARIOGRAM (γ) MEASURES THE DEGREE OF CORRELATION AMONG PLUTONIUM VALUES IN A GIVEN AREA AS A FUNCTION OF DISTANCE AND DIRECTION BETWEEN SAMPLES

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

ISOTROPIC SEMIVARIOGRAM

FIGURE 1-2

February, 1991

cross section through the traditional map will show the variations in concentrations necessary to fit a smooth curve through the data, whereas the kriged section line will show a broad general trend and differs from the data by an average amount corresponding to the nugget effect. Hence, one should not expect to see a kriged contoured map that precisely matches all the observed points, but rather the best linear, unbiased estimate of the general trend of plutonium and americium in the soil environment east of 903 Pad. [An in-depth discussion of geostatistics and precise definition of the various terms used are presented in the introductory textbook (Isaaks and Srivastava, 1989)]

1 3 2 Source of Kriging Variations in Soil-Plutonium Concentrations in Surface Soils

In constructing these spatial distribution estimates the area immediately adjacent to the 903 Pad was excluded from the kriging analysis because of extremely large variations in soil-plutonium (Table 1-1). Hence, the contours of soil-plutonium depicted in Figure 1-1 provide a somewhat skewed distribution of soil-plutonium away from the source. Little, et al (1980) speculated that the large range in plutonium concentrations in Rocky Flats Plant soils may derive from many small plutonium particles agglomerated with large soil particles to form aggregates. In another site, (Aiken, South Carolina) concentrations of plutonium in soils especially near the source were also highly variable with coefficients of variation usually exceeding 1.0 (Pinder and Paine, 1980). They ascribed the variations in plutonium-239,240 to varying distance from point of release (75 percent), microtopographical variations (20 percent) and sampling error, which included subsampling and analytical error (5 percent).

1 3 3 Ground Based Gamma Survey

A ground-based gamma survey of the area east of the 903 Pad was conducted by EG&G/EM during the fall of 1990. The gamma emitting isotopes in the area east of the 903 Pad were measured by High Purity Germanium Gamma Detectors (HPGe). A 150 foot grid spacing was selected to provide 100 percent land coverage. The instrument height was set at 7.2 meters (m) above ground surface. Count time was set at 15 minutes based on the size of the area and number of measurement points needed to be accomplished in a reasonable time frame. The vehicle Mounted System, as set up, had a minimal detectable activity of 0.9 pCi/g for americium-241. These readings represent an averaged americium activity within the top 3 centimeters (cm) of the soil. Plutonium concentrations were derived from the linear relationship between americium and plutonium in Rocky Flats soils ($[Pu] = 6.23 \times [Am]$, R. Reiman, unpublished data). This estimate takes into account the original isotope mix and mixture age (EG&G/Energy Measurements, 1990). Kriging estimates using the linear model were computed for americium and plutonium distributions east of the 903 Pad (Figures 1-4 through 1-7). The letters H and L in these figures represent higher and lower values than the adjacent contours. Locations which contained americium values of less than 0.9 pCi/g were not included in the kriging computations. The radiological data provides an excellent spaced grid for spatial estimation of radionuclides.

TABLE 1-1

SOIL-PLUTONIUM CONCENTRATIONS IN SURFACE SOILS EAST OF THE 903 PAD

<u>Author</u>	<u>pCi/g</u>				<u>Sample Collection Method*</u>
	<u>Number of Samples</u>	<u>Standard Mean</u>	<u>Concentration Deviation</u>	<u>Concentration Range</u>	
Campbell (1984)	19	1024	978	74 - 3700	RFP
DOE (unpublished, samples collected and analyzed in 1990)	10	267	173	2 - 566	RFP
	10	147	90	8 - 283	CDH

* Sample Collection Method
RFP - Rocky Flats Plant

The soil samples are collected by driving a 10 x 10 centimeter (4 x 4 inches) cutting tool 5 centimeters (2 inches) deep into undisturbed soil. The soil sample within the tool cavity is collected and placed into a new one-gallon metal can. Five subsamples are collected from the corners and the center of two one-meter squares, which are spaced one meter apart. Each set of 10 subsamples is composited (5000 cm³) for soil radionuclides analyses.

CDH - Colorado Department of Health

The soil samples are collected by driving a stainless steel sampling device (5.08 x 5.4 x 0.25 cm, 2 x 2 1/8 x 1/4 inches) into an undisturbed soil. The soil sample within the tool cavity is collected and placed into a new one-pint metal can. Twenty-five subsamples are collected from a regional sampling sector or 10-acre area within a specified parcel of land to yield a single composite sample. The sample locations should be more or less evenly spaced within the area. If a single sample is taken from a single sampling location, then the sampling location should be representative of the area of interest. CDH has a set of specific requirements for the sampling location: 1) undisturbed area by anything other than natural causes for as long as possible, preferably for several years, 2) the location is relatively flat, open terrain, and 3) the site does not lie in the shadow of a hillside or other topographic feature that altered wind pattern.

thus relatively small error of estimates were observed near the 903 Pad (Figures 1-5 and 1-7) However, an extremely large reading of americium (91 pCi/g) was observed in one location (Figure 1-4) which reinforced the notion that the spatial distribution of radionuclides near the source point can be extremely erratic

1 3 4 Proposed Work

In order to assess the extent of plutonium, americium, and uranium (U) in surficial soils within the plant boundaries, samples will be collected across the area identified in Figure 1-8 consisting of approximately 800 acres Figure 1-8 was constructed on the basis of the above literature review, data analysis of unpublished material (Figures 1-1 and 1-2), and in-situ radiological survey measurements (Figures 1-4 through 1-7) The State of Colorado requires special techniques for construction on lands with plutonium concentrations greater than 0.9 pCi/g of dry soil To evaluate the soil-plutonium values relative to this guideline the CDH sampling protocol will be used

The CDH sampling protocol requires 25 subsamples to be composited within a 10-acre area for analysis Because of the large variations in soil-plutonium near the source area, a 2.5-acre grid will be sampled immediately east of the 903 Pad and around the East Trenches area (Figure 1-8) This sampling design will serve two purposes (1) increase our confidence in soil-plutonium estimates around 903 Pad and East Trenches Areas, and (2) expand the number of soil data for kriging estimates The pedologic sampling in the 2.5-acre area will consist of 25 subsamples for plutonium, americium, and uranium concentration determination In addition, 25 subsamples will be composited within the 10-acre grid to assess the spatial distribution of plutonium and americium within the buffer zone east of the 903 Pad (Figure 1-8) The northwest corner of each grid will be surveyed and identified with an appropriately marked steel post Grids will be oriented on the cardinal compass directions The 25 subsamples for the composite samples will be located with a hand held compass and tape measure using the northwest corner as the starting point If large concentrations of plutonium (> 10 pCi/g) are detected north of the Mound Area, ten additional 10-acre plots will be added between the Mound Area and North Walnut Creek

1 4 VERTICAL DISTRIBUTION OF PLUTONIUM AND AMERICIUM IN SOILS EAST OF ROCKY FLATS PLANT

1 4 1 Past Work

Several studies investigated the magnitude of plutonium transport down the soil column The intensive study site, which is located approximately 1.5 kilometers (km) east of the 903 Pad (Figure 1-1), was established in 1979 in response to the recommendations outlined by Seed, et al (1971) Soil samples were collected

between 1979 and 1983 to assess the vertical distribution of plutonium in Rocky Flats Plant soils (Rockwell International, 1985) Composite samples were collected from 60- 2m² plots located 1 m apart Samples were taken from 0 to 5 cm and 5 to 20 cm intervals The surface samples were collected using the Rocky Flats Plant method, whereas the subsurface samples were collected using a soil auger The mean and the standard deviation of soil-plutonium concentrations in the surface and the subsurface horizons were 10.2 ± 2.7 pCi/g and 1.1 ± 0.4 pCi/g, respectively The vertical profile of the data distribution suggests that some plutonium has migrated down the soil column Little and Whicker (1978) found that plutonium concentrations in soils east of the 903 Pad increased with decreased particle-size Their studies indicate that the highest plutonium concentrations were associated with sub-micron sized soil particles for all depths (0 to 21 cm) Two-thirds of the total plutonium in the soils were found in the top 5 cm The relationships between plutonium concentrations and soil particle size suggests a surface-attachment mechanism of plutonium to soil particles However, the absence of a consistent trend of soil-plutonium with depth for the various particle sizes indicates that vertical plutonium transport is not simple transport of plutonium down the soil column For example, Krey, et al (1978) found that 90 percent of total deposit of plutonium was held in the upper 10 cm of the soil They recommended a more detailed study of soil characteristics and additional measurements of plutonium concentrations with depth and time at the Rocky Flats Plant

1.4.2 Proposed Work

Twenty-three soil profiles will be excavated, described, and sampled in order to assess the vertical distribution of plutonium-239,240 and americium-241 in soils east of the Rocky Flats Plant Ten soil profiles will be excavated in the immediate vicinity of the 903 Pad, East Trenches, and seep SW-53, and an additional 12 soil profiles will be excavated according to soil types, direction, and distance from the 903 Pad The approximate location of soil profiles are depicted in Figure 1-8 The soil profiles will be dug in undisturbed or the least disturbed sites which are characterized by the natural short grass prairie, pasture, and valley side vegetation (Clark, et al , 1980) The exact location of the soil profiles will be determined in the field using aerial photographs, soil and topographic maps, radiological surveys, and common sense Transport of soil-plutonium in the soil environment is highly affected by soil type, moisture content, texture, structure, and particle characteristics such as shape, density, and cohesiveness (Burley, 1990) Hence, all the major soil types east of the 903 Pad will be sampled (Table 1-2) Soil profiles will be excavated in all soil types east of the 903 Pad to assess the vertical distribution of soil-plutonium

Sampling soil profiles for radionuclides characterization is difficult for the following several reasons

- Potential contamination of subsurface horizons during sampling from the highly contaminated surface horizons

TABLE 1-2
SOIL TYPES EAST OF THE 903 PAD

<u>Series</u>	<u>Family</u>	<u>Phase</u>	<u>Min-Max Slope (%)</u>	<u>Infiltration Rate</u>	<u>Soil Type*</u>
Denver	Torrertic Arguistolls	clay loam	5-9	slow	27
Denver-Kutch	Torrertic Arguistolls	clay loam	5-9	slow	29
Denver-Kutch-Midway	Torrertic Arguistolls	clay loam	9-25	slow	31
Englewood	Torrertic Arguistolls	clay loam	2-5	slow	42
Flatirons	Aridic Paleustolls	sandy loam	0-3	slow	45
Haverson	Ustic Torrifluvents	loam	0-3	moderate	60
Leyden-Primen-Standley	Aridic Arguistolls	cobbly clay loam	15-50	slow	80
Midway	Ustic Torriorthents	clay loam	9-30	slow	98
Nederland	Aridic Arguistolls	sandy loam	15-50	moderate	100
Nunn	Aridic Arguistolls	clay loam	0-2	slow	102
Nunn	Aridic Arguistolls	clay loam	2-5	slow	103
Standley-Nunn	Aridic Arguistolls	gravelly clay loam	0-5	slow	149
Willowman-Leyden	Aridic Arguistolls	clay loam	9-30	moderate	174

* Soil Type number corresponds to soil type exhibited in Figure 1-8

Source U S Department of Agriculture, 1980

- Collection of sufficient sample material for actinides concentrations and other soil chemical parameters
- Selecting the best sampling design to study the chemical trends in the soil profile with little or no cross contamination

In light of these difficulties special attention will be given to surficial soil sampling from the 22 soil profiles using a modified trench method (Harley, 1972). This method involves digging a trench with a backhoe or shovel 1.5 m long, 1.0 m wide and 1.0 m deep. One wall of the trench will be dug as a block/stair case (15 cm height each) to minimize cross contamination. The vegetation at the surface of the selected wall will be cropped closely to the surface and discarded. The soil morphology will be described according to the standard operating procedures for logging alluvial and bedrock material (SOP 3.1, EG&G 1990b). The surficial soil will be sampled at intervals of 3 cm starting at the deepest block/stair in a given pit. Surficial soil samples will be collected using a stainless steel scoop and template (3 cm x 20 cm) which will be pressed into the wall of the block/stair case. Three samples from each depth will be consolidated to provide a better representation of the site and to produce enough soil material for the various chemical analyses described below. After a sample has been collected, the soil layers below it will be cleared of slough to prevent possible contamination from falling soil material from the upper layer. A flag will be placed on the ground surface of a given pit and the depth below surface for each sample will be measured from the base of the flag. Upon completion of the sampling activities each pit will be backfilled with the original soil mixture removed during the excavation.

A site-specific Health and Safety Plan will be developed for the Phase II RFI/RI field activities. The plan will specify stabilization procedures during excavation and surficial soil sampling events to prevent resuspension of particulates. Tarps will be used to cover soil piles and water will be applied to access roads and excavation sites to control dust. Excavation activities will not proceed when sustained wind velocities exceed 15 miles per hour (mph).

1.5 PHYSICOCHEMICAL ASSOCIATION OF PLUTONIUM IN ROCKY FLATS PLANT SOILS

1.5.1 Static Soil Phase - Past Work

Sorption of plutonium (IV) onto mineral surfaces, complexation with naturally occurring organic substances, and carbonate species are the dominant processes in plutonium cycling in the soil environment (Polzer, 1971, Bondietti, et al., 1976). Plutonium in oxidation state (IV) is very insoluble in water in the absence of complexing agents (Bondietti and Tamura, 1980). Onishi, et al. (1981) reviewed radionuclide adsorption/desorption mechanisms in soils and concluded that strong adsorption of plutonium occurs over the pH range of four to eight and is easily complexed with humic acids, oxalate, and acetate ions. Bondietti, et al. (1976) removed

82 percent of the soil-plutonium by repeated bleaching experiment with NaOCl at pH 9.5, which minimized inorganic mineral destruction (Lavkulch and Wiens, 1970), and thus would not extract occluded plutonium in sesquioxides. This removal suggests that a large portion of soil-plutonium is associated with organic carbon (C), and that plutonium is associated with the soil via surface-sorbed mechanisms. The release of organic chelates agents is strongly dependent on pH and decalcification processes within the soil (Bondietti and Tamura, 1980).

Phase I RI found occasional elevated concentrations of plutonium (> 0.05 pCi/l) in seep waters (SW-50, SW-53, and SW-54) (Rockwell International, 1987a). Although the total concentration of plutonium in the soil matrix is important information in appraising the potential hazard, total concentrations do not provide sufficient data to assess potential transport and availability of plutonium in the soil environment. Hence, in order to better understand the mechanisms of transport of plutonium in soils and seep waters, a sequential extraction of soil from five soil profiles above seep SW-53 (locations X1 to X5 in Figure 1-8) will be conducted. Soil samples will be collected at 3 to 5 cm intervals. The procedure for sampling the soil profiles is described above. This study, in conjunction with the soil interstitial waters investigation (Mobile Soil Phase, see below), will provide the necessary information to appraise the nature of plutonium transport in the soils of Rocky Flats.

1.5.2 Static Soil Phase - Sequential Extraction Experiments

Use of total plutonium concentrations as a criterion to assess the potential effects of soil contamination implies that all forms of plutonium have an equal impact on the environment. It is clear that such an assumption is untenable. Kochen, et al., (unpublished) assumed that plutonium has been adsorbed to clay, organic matter, and/or sesquioxides (e.g., Fe_2O_3 - PuO_2). However, no direct measurement was conducted to quantify the type and degree of plutonium adsorption to the various mineralogical phases. Conceptually, the soil can be partitioned into specific fractions which can be extracted selectively by using appropriate extractants (Tessier, et al., 1979). Sequential multiple dissolution techniques which selectively extract soil material with resulting release of its associated metals have been extensively used in soil science and geochemical exploration (Chao, 1984). The purpose of the selective sequential extraction in the proposed study is to elucidate the mode of occurrence and possible transport of plutonium and americium in soils. It should be noted, however, that the partitioning of plutonium and americium obtained by this procedure is operationally defined, as it is influenced by experimental factors such as the choice of reagents, the time of extraction, and the ratio of extractant to soil (Tessier, et al., 1979). In addition, inherent analytical problems such as incomplete selectivity and readsorption may seriously affect the extracted metal concentrations. For example, Rendell, et al. (1980) found that added cadmium (Cd), lead (Pb) and copper (Cu) were readsorbed by uncontaminated river sediments during over-night extraction with selected extractant solutions. Gruebel, et al. (1988) showed that arsenic (As), and selenium (Se), associated with freshly precipitated amorphous iron oxides, were readsorbed onto other minerals unaffected by the reductive extractant. Kheboian and Bauer (1987) doped trace metals into humic acid

(Cu), iron sulfides, zinc (Zn), calcite (Pb), and iron hydroxides [Cu, nickel (Ni)] but failed to recover these metals in the appropriate fraction using the selective procedure outlined by Tessier, et al (1979) These findings imply that selective extraction may not be suitable for distinguishing the phase-association of metals in soils Belzile, et al (1989) have challenged the above results and asserted that postextraction readsorption of metals occurred due to improper experimental conditions of the sequential extraction and mineral phases They quite convincingly showed that trace elements spikes (< 100 percent of the amount present in the control samples) were recovered within the limits given by the experimental errors ± 10 percent

1 5 3 Static Soil Phase - Proposed Work

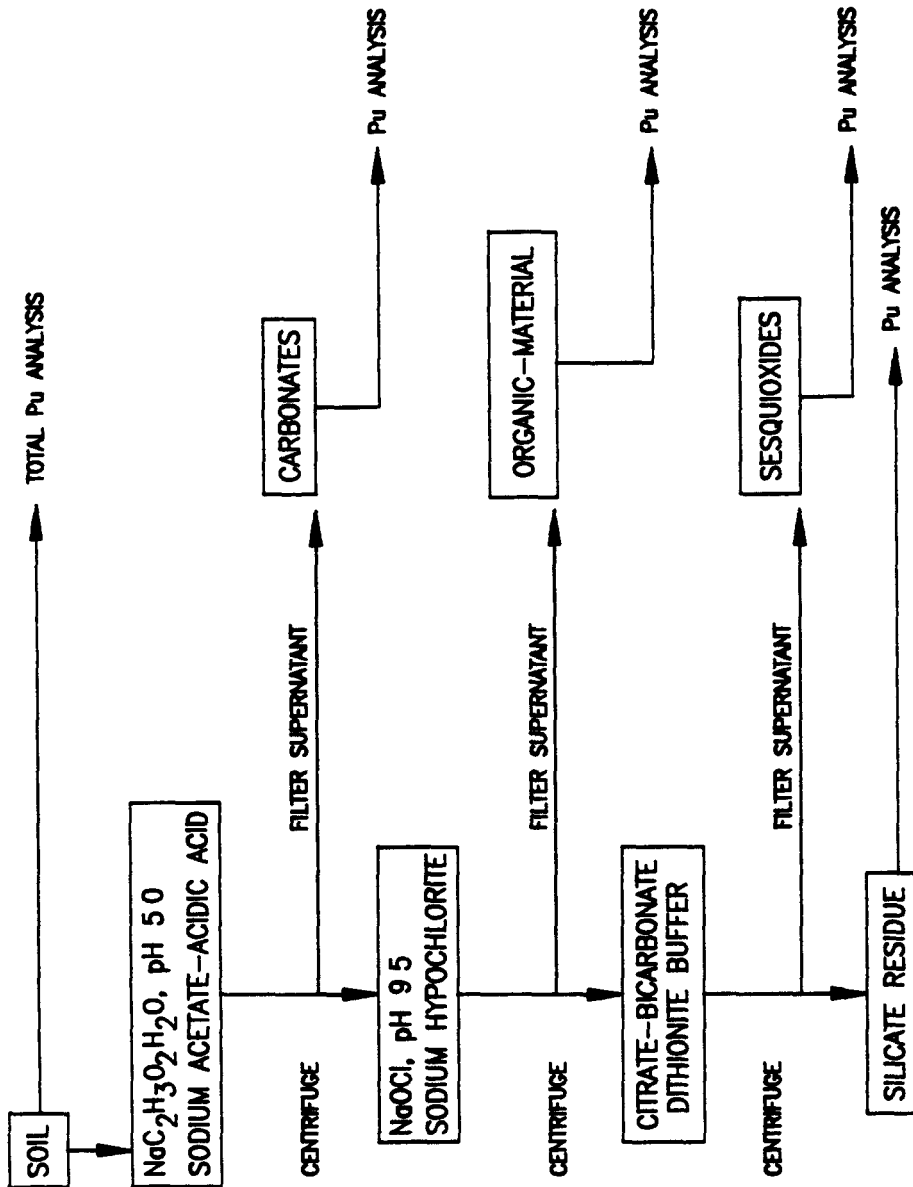
Plutonium determination will be performed on four sequential, selective extracts in triplicates to assess the physicochemical association of plutonium with calcium carbonate (CaCO_3), organic carbon, sesquioxides, and residue (Figure 1-9) In this study, we shall utilize the gamma emitting isotope, plutonium-237, as a tracer to assess the degree of postextraction readsorption of plutonium during the various extractions performed on the soils In addition, the sequence of extractions shown in Figure 1-9 will be modified to test the uniqueness of an individual extraction

1 5 3 1 Tracer Study

Spikes of plutonium-237 will be added to soil samples (triplicates) before each extraction step (Figure 1-9) The distribution of plutonium-237 in the various soil phases and solution and the possible readsorption of the tracer will be carefully determined Plutonium-237 tracer is ideal for this work since its 60 KeV γ emission can be efficiently measured externally using a GeLi detector and a multichannel analyzer (non-destructive technique) This tracer has a physical half-life of sufficient length (45 days) to permit easy measurements over the course of the experiment, yet short enough to decay reasonably rapidly The basic assumption underlying the validity of the plutonium-237 tracer experiments is that the behavior of plutonium-237 is identical to plutonium-239, 240 present in soil Theoretically, the difference in mass between isotopes can cause a shift in the reaction rate or equilibria (the isotope effect) Because the degree of chemical bond stability is directly related to the square root of the mass of the isotopes involved, it is apparent that the isotope effect will not be of significance for high atomic weight elements like plutonium The plutonium-237 tracer will be added in a chemical and physical state similar to that of plutonium-237 to ensure complete isotopic exchange between isotopes in the experimental system Similar data can be obtained for americium-241 since it is also a gamma emitter

In case of serious postextraction readsorption (> 15 percent) the selective sequential extraction will not be performed In case the selective sequential extraction procedure is rejected, samples collected from pits X1 to X5 will only be analyzed for total plutonium

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SEQUENTIAL EXTRACTION FOR SOIL-PLUTONIUM

FIGURE 1-9

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1 5 3 2 Partitioning of Soil Phases

Fraction 1 Carbonates In the soil environment carbonates are susceptible to changes in pH which will induce the release of adsorbed plutonium. Carbonates will be removed by 0.5 molar (M) sodium acetate-acetic acid buffer solution ($\text{NaC}_2\text{H}_3\text{O}_2 \cdot \text{H}_2\text{O}$), adjusted to pH 5. This buffer treatment removes metals held in carbonates (coprecipitate with carbonates and/or adsorbed by iron and manganese (Mn) oxides which have precipitated onto the carbonates) (Jenne, 1977). This buffer apparently does not attack the resistant sesquioxide phases to any great extent and leaves the lattice structure of silicate minerals intact (Chao, 1984).

Fraction 2 Organic In natural conditions organic carbon is gradually decomposed which may lead to release of soluble and colloidal plutonium. The organic carbon will be extracted by NaOCl at pH 9.5. Lavkulch and Wiens (1970) removed up to 98 percent of the oxidizable organic carbon from 16 soil samples by three successive extractions with sodium hypochlorite. The sodium hypochlorite treatment is the preferable solution for extracting plutonium from soil organic matter because it does not appear to dissolve sesquioxide phases. It should be noted, however, that sodium hypochlorite will attack sulfides that may be present in the sample.

Fraction 3 Sesquioxides Sesquioxides are excellent scavengers of trace metals and are extremely unstable under anoxic conditions. There are various techniques to extract iron (Fe), manganese, and aluminum (Al) oxides in soils. These methods were developed to selectively dissolve the various mineralogical forms and degree of fineness of the sesquioxides present in soils. In the context of the proposed study, the citrate-bicarbonate-dithionite buffer method (Jackson, et al., 1986) is superior to other methods because it dissolves amorphous sesquioxides completely whereas the highly crystalline sesquioxides (e.g., hematite and goethite) will be partially dissolved. The degree of dissolution of the highly crystalline sesquioxides is dependent on the crystallinity and the degree of grinding of the oxides. Hence, in order to obtain complete dissolution of crystalline sesquioxides, the soil samples will be finely ground and three multiple extractions will be performed.

Fraction 4 Residue After removal of the above chemical phases from the soil sample, the residue consists of silicates and some other resistant mineral species such as ilmenite and magnetite. The residue will be dissolved by strong digestion with hydrofluoric acid in conjunction with perchloric acid.

1 5 3 3 Experimental Conditions

- (a) Bound to Carbonates The soils will be extracted for 5 hours with 20 milliliters (mL) of 1M sodium acetate-acidic acid solution adjusted to pH 5.0. Detailed description of this extraction is given by Nelson (1982).
- (b) Bound to Organic The residue from (a) will be extracted for 5 hours with 20 mL of 1M sodium hypochlorite solution adjusted to pH 9.5. Detailed description of this extraction is given by Hoffman and Fletcher (1981).

- (c) **Bound to sesquioxides** The residue from (b) will be extracted for 6 hours with 100 mL of 0.3M sodium citrate mixed with 1M sodium carbonate solution and appropriate amounts of sodium dithionite and sodium chloride salts. This extract will be repeated three times to assure almost complete dissolution of highly crystalline iron oxides. Detailed description of the extraction is given by Jackson, et al (1986)
- (d) **Residual** The residue from (c) will be digested by a 5:1 mixture of hydrofluoric (HF) and perchloric (HClO₄) acids. For a 1-gram (g) (dry weight) sample, the soil will be first digested in a platinum crucible with a solution of concentrated HClO₄ (2mL) and HF (10mL) to near dryness. Subsequently, a second addition of HClO₄ (1mL) and HF (10mL) will be made, and again the mixture will be brought to near dryness. Finally, HClO₄ (1mL) will be added and the sample will be evaporated until the appearance of white fumes. Further details of this extraction is given by Lim and Jackson (1982)

After each extraction the sample will be centrifuged at 10,000 revolutions per minute (rpm) for 30 minutes. The supernatant will be removed with a pipet and prepared for plutonium and americium analysis. The residue will be washed with 10 mL of deionized water to remove residual salt from the previous extraction. The volume of the rinse water will be kept at a minimum to avoid excessive solubilization of organic matter.

In addition to plutonium and americium determination, the following laboratory analyses will be conducted on all samples from the 23 soil profiles: (1) total organic carbon, (2) pH, (3) calcium carbonate content, and (4) specific conductance. The specific conductance will be used to estimate the ionic strength of the soil slurry (Lindsay, 1979). All samples from the 23 profiles will also be subjected to the carbonate and organic carbon extraction experiments described above. Residual extractions will be performed to determine the percentages of primary and secondary minerals. The samples collected from pits X1 through X5 (Figure 1-8) will also be subjected to the sesquioxide and residual extraction experiments. Particle size analyses and bulk density testing will also be performed on samples from selected profiles. Specifically, a sample from a profile representative of each soil type (Table 2-2 and Figure 2-6 of the alluvial work plan) will be submitted for these geotechnical tests.

1.5.4 Mobile Soil Phase - Past Work

Reports of plutonium and americium movement in ground water over distances beyond several meters are rare. Hakonson, et al (1981) reviewed the transport of plutonium in terrestrial systems and asserted that vertical leaching of soluble plutonium through the soil is a potentially important phenomenon. Onishi, et al (1981) concluded that adsorbed plutonium can be readily moved through the aqueous environment in colloidal form. Recently, Penrose, et al (1990) found that plutonium and americium were transported in ground water for at least 3390 meters downgradient from the point of discharge where plutonium and americium were tightly or irreversibly bound to colloidal material [25 to 450 nanometers (nm)]. Krey, et al (1978) attributed the successful application of the diffusion term in their soil-plutonium transport model, at several diverse sites east of the 903 Pad, to transportability of plutonium in soil interstitial waters and not to soil characteristics.

Little research has been conducted on the transport of actinides within the soils and to seeps and streams at the Rocky Flats Plant. Moreover, there are no studies on the physicochemical characteristics of interstitial waters in soils and sediments from Individual Hazardous Substance Sites (IHSSs) on plant-site. The excavation of 22 soil profiles will allow for the installation of automated soil solution samplers in order to measure and characterize the movement of water and radionuclides down the soil column. More specifically, soil solution samplers will be installed in the soils above seeps SW-50, SW-53, and SW-54 to study the movement of both water and radionuclides (colloidal and dissolved) down the soil column and to the seeps downslope.

1.5.5 Mobile Soil Phase - Proposed Work

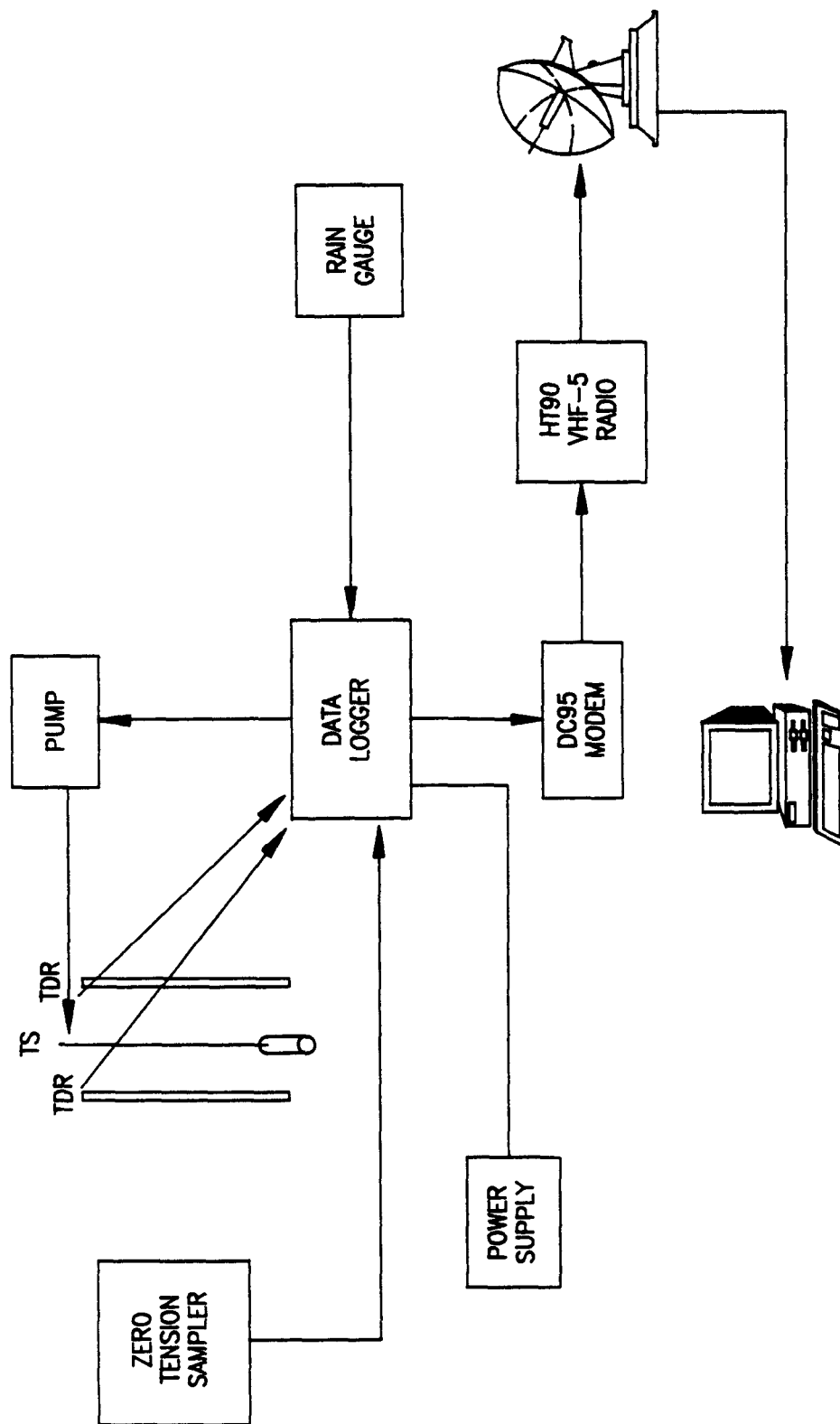
Environmental fate of actinides in soils are usually studied by extracting the soil matter. In general, these analyses fail to provide important information regarding the transport mechanisms of pollutants within the soil column. Hydrological analysis of the frequency, duration and intensity of summer precipitation events and spring snowmelt events, coupled with direct measurements of solute transport in soils, will provide essential information to assess the form and magnitude of actinide movement in soil.

The proposed research design is based on the following three hypotheses:

- Leaching episodes in the soils will transport solute and colloidally-bound actinides down the soil column.
- Freely flowing waters in the soil environment will carry different actinide concentrations than soil solutions collected at higher matrix potentials.
- The occasional elevated concentrations of plutonium in seep SW-53 were originated by vertical leaching of plutonium from the soil environment upslope.

Testing these hypotheses will require *insitu* sampling of soil interstitial waters over time. More specifically, it will be necessary to develop a fully-automated, remote-controlled soil solution sampling system that is capable of (a) collecting freely flowing water [0-5 kiloPascals (kPa) matrix potential] mainly via macropores, (b) collecting soil solutions flowing in micropores at higher matrix potential (5-40 kPa), and (c) provide accurate and timely measurements of incoming precipitation. This apparatus will consist of five major modules: an automated zero-tension sampler, in which freely flowing water mainly in macropores (formed by frost heave cycles and swelling and shrinking of clays), will be accurately collected for assessing the subsurface flow during and after major precipitation events, a fluxmeter which will provide the unsaturated flux as the soil dries out as well as soil solutions for radiochemistry analyses, tipping bucket rain gauge, time domain reflectometry (TDR) soil moisture probes which will measure *insitu* soil water content, and telemetry communication which will send the data collected in the field to a base station at T130B (Figure 1-10).

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TDR = TIME DOMAIN REFLECTOMETRY

TS = TEFLON CYLINDER TENSION SAMPLER

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SOIL SOLUTION SAMPLER APPARATUS

FIGURE 1-10

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The objectives of the proposed work are to

- Estimate the importance of vertical flow in the soil environment upslope from seep SW-53 during and after major precipitation events
- Assess the relationships between soil-plutonium in the interstitial waters and plutonium in the seep SW-53

The water flow data obtained insitu will be used to test the infiltration rates and flow estimates for the unsaturated flow model, being developed by Colorado State University (CSU) (mid-1991), for the area east of the 903 Pad. The chemical characterization study will include (1) total concentrations of plutonium and americium in soil interstitial waters that move freely (0-5 kPa) down the soil column, and (2) fractionation of actinides in colloidal and dissolved (< 0.1 micrometer [μm]) phases in freely flowing waters (0 - 5 kPa) and various matrix potentials (5 - 10, 10 - 30, 30 - 50 kPa).

1 5 5 1 Soil Solution Samplers

The chemical characterization will be performed using the soil solution sampler equipment described in the following sections. These samplers will include zero-tension samplers and fluxmeters.

Zero-tension sampler

The zero-tension sampler will be made of 40-cm segments of plexiglass (25 cm width) with one end plugged with a plexiglass stopper containing a collecting tube and the other end sharpened. The sharpened end will be driven into the western pit face of pits X1 through X5 (Figure 1-8) with a mallet to ensure minimal structure and textural disturbance to the soil. The water sampled by the zero-tension sampler will be collected by a 2-liter (l) bottle mounted on a load cell. The temperature of the soil interstitial waters and the soil matrix will be measured by a temperature probe. The temperature and amount of water in the collection bottle will be simultaneously transmitted to a data logger. The transmitted information will be transferred daily to the base station via telemetry. Sending the data via telemetry to the base station (trailer T130B) will provide crucial information regarding the time and frequency of field sampling.

The soil pits will be refilled after access tubes are inserted to prevent convergence flow and to minimize further disturbance. The zero-tension soil solution samplers will be installed upslope of seep SW-53 every 10 to 15 cm down the soil column to the depth of the caliche horizon or other semi-impermeable layer in the five soil pits.

Fluxmeter

The fluxmeter consists of three components a Teflon cylinder soil water sampler which is treated with silica to reduce hydrophobicity, three TDR soil moisture probes, and a portable vacuum pump with a buffer container. Each Teflon sampler will be installed with three TDR soil moisture probes around it and connected, via Teflon tubing, to a 2-l collecting bottle equipped with a special screw cap of polyethylene with teflon gasket and fittings. The 2-l collecting bottles will be residing inside a thermo-box which will minimize temperature fluctuations in the field. Two types of Teflon cylinder soil water samplers will be used a teflon cylinder with an average pore size of 10 μm for sampling large water volumes during short flow episodes, and a teflon cylinder with an average pore size of 5 μm for normal operational conditions. Ten Teflon cylinder soil water samplers will be installed at five different depths in each pit (X1 through X5, Figure 1-8) excavated for the zero-tension sampler. The Teflon cylinder soil water samplers will be installed into the face of the soil pit using a stainless-steel rod. The soil moisture probes will be connected via coaxial cable to a Tektronix cable tester, equipped with a communication interface, to a data logger (Figure 1-11). Once the moisture of the soil exceeds a pre-set value the vacuum pump will be activated to produce an equivalent vacuum inside the tension sampler. The equivalent vacuum will be derived from the linear relationships between soil moisture and matrix potential values in the range of 0.1 to 50 kPa.

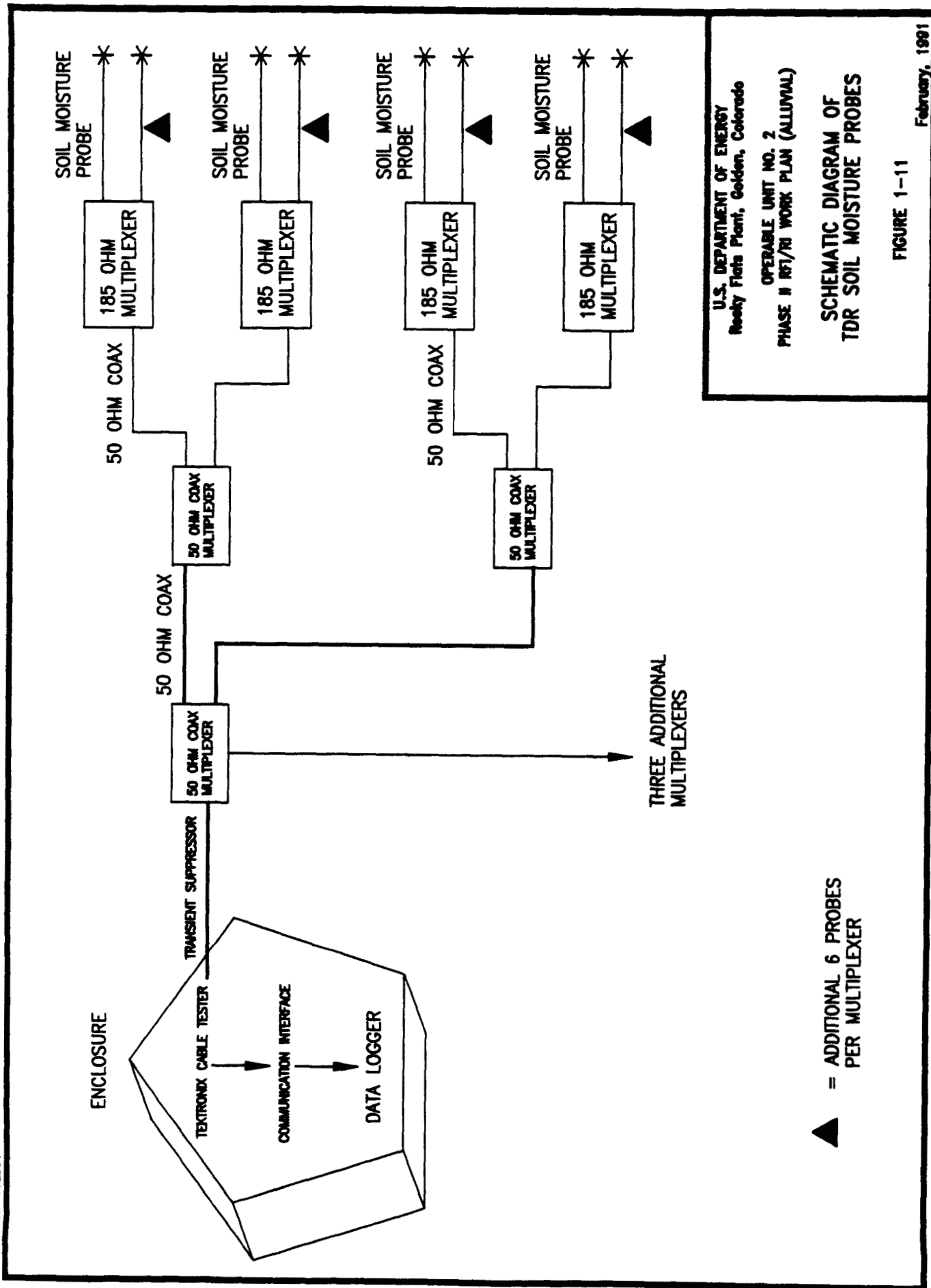
The soil interstitial waters collected by the zero-tension samplers and the tension samplers will be filtered on the day of sampling using 0.45- and 0.1- μm Millipore filters. The total colloidal bound plutonium will be determined from the material that was retained on the filters. The dissolved plutonium will be determined from the water that passed through the filter.

1.5.5.2 Precipitation Events Simulation

The frequency, duration and intensity of summer precipitation will be determined by a tipping bucket rain gauge. This rain gauge is an integral part of the proposed apparatus and will be mounted in the middle of the transect. The rain gauge will simultaneously transfer the data to the data logger which will transmit this information via telemetry to the base station in T130B. The amount and nature of precipitation and soil water flux will be recorded and checked daily. The frequency of field sampling will be determined on the basis of the transmitted data. This data will be used to prepare a precipitation model for hydrologic simulation and analysis.

The amount of water that can be collected by this apparatus in Rocky Flats Plant soils is currently unknown. One to two liters of interstitial waters were collected every week during snowmelt and after every major

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**SCHEMATIC DIAGRAM OF
 TDR SOIL MOISTURE PROBES**

FIGURE 1-11

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precipitation event in forested and alpine ecosystems using a simplified version of the proposed apparatus (Litaor, 1988). Hence, two rain simulation experiments will be conducted before the beginning of the Figure 1-11 precipitation season. The first experiment will be used to verify that all the components of the apparatus are interfacing and communicating with each other and the base station. Calibration of the load cells and the TDR soil moisture probes will be performed during the first rain simulation experiment. The magnitude and duration of the second simulated rain will be determined by reviewing precipitation data collected at Rocky Flats Plant in the last five years to determine the magnitude and duration of storm events. Soil solution collected during the second simulation experiment will be submitted for radionuclides analyses.

The importance of hydrologic model simulation of rain and snow precipitation in the proposed work can be summarized as follows: (1) rain simulation yields more rapid results, especially in the testing of the extreme conditions (e.g., rainfall in arid and semi-arid conditions), and (2) rain simulation is more controlled inasmuch as one can take appropriate measurements with selected intensities and durations. The rain simulator described by Ghodrati, et al. (1990) will be used in the proposed work. This rain simulator can employ spatially uniform application of water to small plots (1-2 m²). The simulated rainwater will have the same ionic strength as the average rainwater observed at Rocky Flats Plant.

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GLOSSARY OF ACRONYMS

ARARs	Applicable or Relevant and Appropriate Requirements
CPOM	Coarse Particulate Organic Matter
DQOs	Data Quality Objectives
EE	Environmental Evaluation
EEW	Environmental Evaluation Work Plan
EMAD	Environmental Monitoring and Assessment Division
EPA	U S Environmental Protection Agency
ER	Environmental Restoration
FSP	Field Sampling Plan
GFFA	Graphite Furnace Atomic Absorption Spectroscopy
HSPs	Health and Safety Plans
ICP	Inductively Coupled Argon Plasma Emission Spectroscopy
IHSS	Individual Hazardous Substance Sites
m	meter
ml	milliliters
mm	millimeters
nm	nanometers
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PPE	Personal Protective Equipment
QAPJP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RBP	Rapid Bioassessment Protocols
RCRA	Resource Conservation and Recovery Act
RFI/RI	RCRA Facility Investigation/Remedial Investigation
SID	South Interceptor Ditch
SWMU	Solid Waste Management Unit
μ	micron

ENVIRONMENTAL EVALUATION FIELD SAMPLING PLAN

2.1 INTRODUCTION

The Field Sampling Plan (FSP) for the Operable Unit Number 2 (OU No. 2) Environmental Evaluation (EE) describes the program for sampling of biota within and near the operable unit in order to assess the ecological consequences of releases of contaminants. The EE FSP will be thoroughly integrated with the RCRA Facility Investigation/Remedial Investigation (RFI/RI) field sampling program at OU No. 2 and ongoing sampling by the Rocky Flats Environmental Monitoring and Assessment Division (EMAD). It is these programs that provide data on contaminant concentrations and extent of contaminant migration in surface water, ground water, sediments, soils, and air.

The OU No. 2 field sampling procedures have been developed following protocols recommended by the EPA (1987, 1988, 1989a, 1989b), the U.S. Fish and Wildlife Service (1981a, 1981b), and those currently being used at the Rocky Flats Plant. The FSP will follow the Quality Assurance Program Plan (QAPJP) and Data Quality Objectives (DQOs) developed for the RFI/RI program as well as the standard operating procedures used by the EMAD for current field monitoring operations (Rockwell International, 1989, EG&G, 1990a and 1991d). Sampling procedures will also conform to existing and new health and safety plans, sample and waste management protocols, and EE-specific data quality objectives (EG&G, 1990a, EPA, 1987).

The field sampling program will consist of a qualitative field survey conducted in the Spring, followed by two quantitative field sampling events in late Spring - early Summer and in late Summer - early Fall. Although the initial field survey will be primarily qualitative, limited quantitative samples and water/soil quality measurements will be taken (Section 2.3). Likewise, during the two quantitative sampling efforts, the sampling teams will record qualitative observations of flora and fauna to assist in interpretation of the field data collected during the program. The initial qualitative survey will be scheduled to coincide with the start of the growing season of prairie vegetation.

As recommended in the U.S. Environmental Protection Agency (EPA) Environmental Evaluation Manual (EPA, 1989a), the ecological field sampling at OU No. 2 will be carefully integrated with the RFI/RI sampling for OU No. 2 in order to coordinate the water, sediment, soil, and air sampling efforts with the ecological sampling (see Section 5.0 of this RFI/RI Work Plan). It will be especially important to schedule the surface water and sediment sampling to coincide with the periphyton and benthic macroinvertebrate sampling. Where possible, vegetation, root, and microbe sampling will be located

in the same areas and scheduled to coincide with soil sampling. In addition to planning sampling events during the same time frame, the ecological evaluation staff will review RFI/RI sampling procedures and analytical protocols for water, sediment, soil, and air samples so that the data necessary to develop and model exposure pathways will be available from the RFI/RI program.

The ecological field sampling at OU No. 2 will be integrated with the ecological field sampling at OU No. 1 so that the data produced at these two adjacent operable units are compatible. It is assumed that periphyton, benthic macroinvertebrate, and fish data from three or more stations sampled as part of the OU No. 1 field effort will be made available to the OU No. 2 field program. If appropriate, the OU No. 1 and OU No. 2 comparative ecology studies may use the same reference areas. Also, the OU No. 2 field sampling team will work closely with EG&G to integrate this sampling plan and the ecological assessment effort with appropriate physical, chemical, or ecological sampling conducted by the EMAD.

The Spring qualitative field survey will be a reconnaissance assessment involving systematic documentation of specific visual observations and collection of qualitative and quantitative field samples that can be processed in the field. Since this survey involves limited data generation and analysis of samples and water/soil quality data in the field, its effectiveness depends to a large extent on the experience of the professional biologists performing the survey. These biologists must have impact assessment experience as well as experience in field ecology surveys in the types of habitats present at OU No. 2.

2.2 SAMPLING OBJECTIVES

The RFI/RI sampling program will provide data on the concentrations of contaminants in environmental media (i.e., water, air, soil, sediments), the plume characteristics, the source characterization, and the extent of contaminant migration within and near OU No. 2. This source characterization will allow the EE project team to compare contaminant concentrations at exposure points to Applicable or Relevant and Appropriate Requirements (ARARs) and other environmental criteria, and assess the ecological significance of the contaminants. Contaminant concentrations will also be compared to the toxicological literature to determine if on-site concentrations could potentially be toxic to the aquatic and terrestrial species present at OU No. 2, if applicable data is available on the contaminants of concern. Contaminant concentration data will also be used to develop quantitative dose-response assessments of toxicity, providing that adequate information is available on exposure in order to compare actual intake rates with acceptable intake rates.

The ecological field sampling program has two overall objectives

- 1 Characterize biological resources in order to conduct the ecological impact assessment by supplementing the RFI/RI database
- 2 Acquire the data necessary to measure ecological effects of contaminants that cannot be assessed by the dose-response and comparison-to-criteria approaches

In general, the ecological field sampling program will provide data necessary to compare aquatic and terrestrial populations or communities at impacted and reference areas, measure toxicity directly, or measure the accumulation of contaminants in plant and animal tissue. As stated in the introduction, the field sampling program is divided into two components: qualitative surveys followed by quantitative field sampling. The objectives of the qualitative surveys are as follows:

- Acquire additional site-specific data on plants, animals, and habitat types at OU No. 2 to assist in identifying potential exposure pathways
- Acquire data needed to characterize the major ecosystem components in and adjacent to OU No. 2
- Determine the presence, absence, and distribution of plant and animal receptors within and near OU No. 2
- Identify threatened or endangered species, critical habitats, and sensitive species that are of concern at the Rocky Flats Plant and OU No. 2
- Acquire information needed to "fine-tune" the quantitative sampling plans presented in this FSP
- Select reference (unimpacted) stations for terrestrial and aquatic sampling purposes
- Observe and document obvious indications of contamination and, if possible, impacts on biota or habitats
- Fill gaps identified during review of existing data

The objectives of the quantitative ecological field sampling program are as follows:

- Acquire additional information needed to assess seasonal changes in habitat types and document the presence and distribution of biological species
- Measure ecosystems for composition, productivity, standing crop or biomass
- Collect quantitative data to estimate intake rates, exposure times, and food chain relationships
- Measure indicators of toxicity (ecological endpoints) and assess the differences between endpoints in populations and communities in impacted and reference areas

- Measure toxicity directly by standard EPA biomonitoring methods
- Measure accumulation of selected inorganics and radionuclides in plant and animal tissue
- Fill data gaps identified during the literature review and the qualitative field surveys

2.3 QUALITATIVE FIELD SURVEYS

The purpose of the qualitative field survey is to develop a thorough familiarization with site characteristics in order to guide the quantitative field surveys. All features of OU No. 2 will be covered in the reconnaissance field surveys, including topography, drainages, soils, aquatic habitats, vegetation, animals, wetlands, and other biota and habitats.

This FSP was based in part on information produced by the Phase I RI and, more specifically, on a recent site visit to OU No. 2. During this site visit, a portion of the source area (Mound and East Trenches Areas) was traversed on foot so that observations could be made on general conditions. Windshield and walking surveys were made in the drainages of South Walnut Creek and Woman Creek, and on the flat grassland and slopes to the east of the source areas. The relationship of the source areas to surface water springs and seeps, and associated wetlands, along with ponds and streams below or adjacent to the source areas, was noted.

The initial qualitative field survey will be conducted in the Spring of 1991, coinciding with the start of the growing season of grassland vegetation. The survey will be designed to meet the objectives stated in Section 2.2. The survey will be designed to describe the aquatic and terrestrial ecosystems at and in the vicinity of OU No. 2, identify the biota and habitats present, further define the conceptual model of contaminant transport by biotic and abiotic mechanisms, and select reference areas for comparative ecological studies. The initial survey will also be used to confirm the sampling locations, frequencies, and protocol for the quantitative sampling effort to be conducted later in the Spring and Summer.

The initial qualitative survey will include locating and evaluating all sampling sites selected for quantitative sampling, including several potential reference areas. The survey will include documenting visual observations, collecting some vegetation, benthic macroinvertebrate, and fish samples, and testing aquatic and terrestrial habitats with field instruments to detect indications of contamination (e.g., the presence of volatile organics in soil or seep areas, or specific conductivity and pH changes in aquatic systems). All observations will be recorded in field logbooks. Field instruments will be checked and calibrated daily.

The qualitative field surveys will be planned in advance to provide the following information

- Physical description of all sampling sites
- Documentation of similarities and differences between the reference areas and on-site sampling locations
- Identification and initial inventory of plant and animal species
- Results from field instrument readings
- Vegetation/habitat map and descriptions of principal habitats
- Description and location of critical or sensitive habitats, list of threatened or endangered species observed
- Description of the principal exposure pathways and conceptual model of principal food chain relationships
- Qualitative description of benthic macroinvertebrate and fish communities at stations along Woman Creek and South Walnut Creek
- Qualitative descriptions of wetland and prairie grassland communities, including identification of dominant and subdominant species
- Descriptions and locations of obvious signs of impact on terrestrial vegetation or aquatic communities
- Relative abundance of key terrestrial and aquatic receptors

Sections 2 3 1, 2 3 2, and 2 3 3 describe the qualitative field surveys of aquatic ecosystems, terrestrial ecosystems, and reference areas

2 3 1 Aquatic Ecosystems

The initial qualitative field survey of aquatic habitats will be along Woman Creek and South Walnut Creek as well as the South Interceptor Ditch from the apparent headwaters down to the surface water sampling stations below Pond C-2 and Pond B-5. Pond C-2 and Pond B-5 are the lowermost ponds at the Rocky Flats Plant within the Woman Creek and South Walnut Creek drainages, respectively. Since there is usually no measurable flow downstream of these ponds, there are no plans to sample aquatic organisms along the lower reaches of South Walnut Creek and Woman Creek between these ponds and the downgradient limits of OU No. 2. An ecologically similar section of Rock Creek, in the northern buffer zone, will be included in the walkover survey to identify potential reference areas for quantitative sampling (Section 2 4) and conduct a comparative assessment of Rock Creek and Woman Creek.

Also, the qualitative field survey will include observations and qualitative sampling at all seep areas identified in the OU No 2 area during the Phase I RI. The survey will result in descriptions of the physical and biological characteristics of sampling stations planned for the quantitative sampling program, potential reference areas, and ground water seeps within OU No 2.

The physical characteristics of stream sections (including the South Interceptor Ditch) and ponds will be documented in the field logbook and on field survey maps. Descriptive parameters such as stream width and depth, pool/riffle ratios, water velocity, bottom substrate, bank vegetation, proportion of undercut banks, fish cover, and channel morphology will be recorded. In situ measurements of water temperature, specific conductivity, pH, and dissolved oxygen will be taken with field instruments along the creeks and at seeps to document potential contaminant and/or ground water inflow. Measurements will be taken above and below locations where surface water enters the creek, and above and below locations where there are indications of possible ground water inflow (e.g., a change in turbidity) or environmental stress (e.g., an increase in filamentous algae).

The biological characteristics of stream sections, ponds, and seeps will be described using three techniques:

- 1 Qualitative observations of filamentous algae, slimes, aquatic macrophytes, and vertebrate and invertebrate animals
- 2 Qualitative sampling of fish with short seines and dip nets
- 3 Sampling of benthic macroinvertebrates utilizing the Rapid Bioassessment Protocols (RBP I) developed by EPA (1989a) for cost-effective assessments of lotic systems

Fish collected by seines and dip nets will be identified, measured (total length), and released. Abnormalities such as fin rot, lesions, and external parasites will be recorded.

The RBP I reconnaissance assessment technique for benthic macroinvertebrate communities will be used to discriminate obviously impacted and nonimpacted areas from potentially affected areas requiring further investigation. The RBP I method focuses on qualitative sampling of benthos, supplemented by a preliminary examination of other aquatic biota such as periphyton, macrophytes, fish, and slimes. At least half of the aquatic sampling stations selected for quantitative sampling will be assessed using the RBP I technique. Standard field data sheets will be used to record the relative abundance of macroinvertebrate orders (Families for Megaloptera and Diptera), occurrence of periphyton, algae, aquatic macrophytes (plants), abundance of fish by species, and water quality measurements.

The results of the qualitative field survey will be summarized in a Technical Memorandum. The major components of this Technical Memorandum are listed in the Introduction (Section 2.3). The occurrence of potential contamination along Woman and South Walnut Creeks and the South Interceptor Ditch will be defined based on results of field water quality measurements, observations of obvious contaminant impacts such as stressed vegetation or absence of aquatic organisms, and biological indicators. Some examples of biological indicators include changes in species diversity, absence of pollution-sensitive taxa or dominance of pollution-tolerant taxa, abundance of filamentous algae, or large differences in reference and impacted areas. The Technical Memorandum will also include recommendations for revisions to the quantitative sampling program, if warranted, and the rationale for those changes. The qualitative survey could result in the addition, deletion, or revision of some of the quantitative sampling locations described in Section 2.4.

2.3.2 Terrestrial Ecosystems

The qualitative field surveys for the terrestrial ecosystems will follow a similar protocol and timing as for the aquatic ecosystems. The entire area of OU No. 2 will be walked to identify terrestrial communities and general ecosystem components. Information developed during the field survey will be verified using information from other sampling programs on the blots in the area of OU No. 2. Observations will be made on species present and voucher specimens will be collected. Information will be collected on general distribution of plant and animal species, boundaries of plant community types and habitats, relationships to soil types, and the physical and biological condition of the vegetation and habitats. Wetlands around springs and seeps and along drainages will be located and delineated for later quantitative sampling. All observations will be recorded in field logbooks and voucher specimens will be given a unique identification.

The physical limits of the proposed sampling locations will be determined. A reconnaissance will be conducted of the vegetation, small and large mammals, predators, birds, and signs of animals (tracks, scat, skeletons, burrows, etc.). At sampling locations close to the source areas, obvious signs of impacts or effects of contaminants will be recorded. Observations on recent biological activities that may impede or increase the movement of soil- or water-borne contaminants will be noted. In particular, a visual survey will be made for ants and fossorial animals such as gopher which bring large amounts of subsurface soil to the surface where it is distributed by wind. Observations will also be made for badgers and foxes which excavate dens or dig in search of prey. The areas close to the source areas will then be systematically surveyed for amounts and kinds of soil and subsoil disturbances by animal activity, and an intensive study of these activities will be performed if warranted.

The selection of species or ecosystem components to be collected for quantitative sampling or tissue collection will be verified. Based on information from the Phase I RI, the wetland plant communities developed around springs and seeps downgradient of the source areas may be sensitive indicators of contaminant migration via the ground water pathway. Wetland plant communities are known to filter and accumulate contaminants such as heavy metals. These wetland areas will be examined for evidence of contaminant accumulations. A second component that may accumulate contaminants are roots of grassland species and microbes growing in contaminated soils, either through root uptake or adherence of particles. A preliminary assessment of rooting depths and densities will be conducted at selected locations by shallow hand-dug trenches and gridding of root depths on exposed soil faces.

Qualitative surveys for mammals, birds, and reptiles will be conducted by systematically walking the area on preselected routes at appropriate times. Bird surveys will be conducted at dawn and dusk. Records will be kept of species and other features observed such as numbers, condition, habitat, and activities. Other evidence of animals or birds including burrows, scat, and nests will be recorded. Checklists will be prepared for the qualitative surveys of animal and plant species to record survey information.

The results of the qualitative field surveys for terrestrial ecosystems will be included in the Technical Memorandum discussed in Section 2.3.1. The specific conditions of the grassland and wetland ecosystems will be discussed as they relate to exposure pathways. Obvious indicators of stress related to contamination including pathological conditions such as necrosis, chlorosis, and stunting of vegetation will be described. Other indicators are the diversity and abundance of species in impacted areas. Revisions in the quantitative sampling plan may result from the qualitative survey.

2.3.3 Reference Areas

The use of reference areas is a potential method of comparing impacted and nonimpacted areas as discussed in Section 6.2.2.4 of the Alluvial Work Plan. Reference areas for appropriate aquatic and terrestrial ecosystems will be selected during the qualitative survey. These areas will generally be upwind of and upgradient from OU No. 2 to avoid contamination. The number of reference areas chosen and their size will reflect the major vegetation and aquatic types determined in OU No. 2 during the qualitative surveys. As a practical matter, generally one reference area for each major ecosystem type will be chosen. Reference areas will be chosen to separate the effects of contaminants from those of physical disturbance. This will be accomplished by keeping the physical characteristics of the reference areas as similar as possible to those of the operable unit, and controlling access and sampling disturbance. The reference and on-site areas will be similar in topography, soils, water chemistry and ecosystems present.

2 4 QUANTITATIVE FIELD SURVEYS

Quantitative sampling of aquatic and terrestrial ecosystems at OU No 2 will be conducted primarily to characterize the ecosystems and measure the ecological consequences of contaminants released from the source areas. The quantitative sampling program will include characterizing the biota at selected sampling stations, conducting comparative ecological studies, measuring contaminant bioaccumulation, and measuring potential toxicity of creek and pond water at selected locations on Woman and South Walnut Creeks. The quantitative sampling will supplement qualitative survey information used for characterizing the ecosystems, identifying major plant and animal receptors, and developing exposure pathways. Qualitative observations will continue to be recorded when field biologists are conducting quantitative sampling.

Field sampling operations for conducting comparative ecological studies, measuring bioaccumulation in selected species, and measuring potential toxicity of water are described in the following FSP sections and in Sections 6 2 2 4 and 6 3 3 of the Alluvial Work Plan. The field procedures will be carefully integrated with similar ecological assessment field studies at OU No 1, with the National Pollutant Discharge Elimination System (NPDES) program at the Rocky Flats Plant which assesses water quality of plant discharges (including Ponds C-2 and B-5), and with routine monitoring and special sampling events conducted by the EMAD. Selection of sampling locations will be coordinated with other RFI/RI sampling, specifically for surface water, sediment, and surficial soil sampling locations. The planning and preparation for field sampling at OU No 2 will include development of sample and waste management protocols that are integrated with, and in conformance with, sample and waste management procedures and Quality Assurance/Quality Control (QA/QC) requirements for the Environmental Restoration (ER) Program.

2 4 1 Aquatic Ecosystems

The FSP for aquatic communities will include sampling periphyton, benthic macroinvertebrates, and fish at selected stations on Woman Creek, South Walnut Creek, and the South Interceptor Ditch (SID). Ground water seeps and one or more reference areas will also be sampled. Reference areas will be selected for comparative ecological studies of creek stations. However, because the ponds on Woman Creek and South Walnut Creek are operated to control any potential contaminant releases (and are not intended for wildlife or recreational use), the FSP will not establish reference areas for the pond habitat.

The stations selected for quantitative sampling are listed in Table 2-1 and shown on Figure 2-1. The locations may be modified following the qualitative field survey in the Spring of 1991. As indicated in Table 2-1, a few stations are designated for both the OU No 1 and OU No 2 field programs. In these

TABLE 2-1
SAMPLING STATIONS FOR AQUATIC ECOLOGY – OPERABLE UNIT NO 2

Drainage	Station No	Aquatic Sampling			Description
South Interceptor Ditch	SW-A	Periphyton	Benthos	Fish	Upgradient of OU No 1 and OU No 2
	SW-70 ^a	Periphyton	Benthos	Fish	Between OU No 1 and OU No 2
	SW-54	Periphyton	Benthos		Downgradient of OU No 2
Woman Creek Watershed	SW-B	Periphyton	Benthos	Fish	Upgradient of OU No 1 and OU No 2
	SW = 32A ^b	Periphyton	Benthos	Fish	Between OU No 1 and OU No 2
	SW-C1	Periphyton	Benthos	Fish	Pond on Woman Creek
	SW-28	Periphyton	Benthos	Fish	Downgradient of OU No 2
	SW-C2 ^a	Periphyton	Benthos	Fish	Pond collecting SID water
	SW-26 ^c	Periphyton	Benthos		Most Downgradient Station, Pond C-2 Discharge
South Walnut Creek Watershed	SW-23	Periphyton	Benthos	Fish	Downgradient of Mound Area and Building 991
	SW-B4	Periphyton	Benthos		Pond on South Walnut Creek
	SW-24	Periphyton	Benthos		Downgradient of Pond B-4
	SW-B5	Periphyton	Benthos	Fish	Lowest Pond on South Walnut Creek
	SW-25 ^c	Periphyton	Benthos		Downgradient of Pond B-5
Ground Water Seeps	SW-55 ^c		Benthos		Downgradient of 903 Pad (Source Area)
	SW-53		Benthos		Downgradient of 903 Pad and East Trenches
	SW-65		Benthos		Downgradient (south) of Trenches and Spray Field
	SW-103		Benthos		Downgradient (north) of Trenches and Spray Field
Reference	SW-C	Periphyton	Benthos	Fish	Upper end of Woman Creek or Rock Creek

^a Stations SW-70, SW-32, and Pond C-2 will be sampled for Operable Unit No 1 and Operable Unit No 2

^b Recommended aquatic samples be taken at SW-32A (alternate) rather than SW-32 so sampling station is closer to the dividing line between OU No 1 and OU No 2

^c Stations SW-26 on Woman Creek (below Pond C-2), SW-25 on South Walnut Creek (below Pond B-5), and ground water seeps (SW-53, 55, 65, and 103) apparently do not have enough water flow for artificial substrate (periphyton) samplers

cases, the stations should be sampled by only one field crew, with the results of the field sampling being submitted to the project staffs for both operable units

2 4 1 1 Periphyton

The periphyton communities at reference and test sites will be monitored using standardized artificial substrate (plexiglass) samplers suspended in the water column. Samplers will be anchored at each station and exposed for the full colonization period. Water quality data will be collected weekly during the exposure period, and the physical and biological characteristics of the sampling station will be documented. At the end of the colonization period, the periphyton will be scraped off the plexiglass slides and analyzed for species or genera, species diversity, biomass, and chlorophyll content. Field sampling procedures will conform to SOP 5.1, Ecology 5.0 (EG&G, 1991d).

Location/Frequency

Periphyton samples will be collected at 12 locations on the South Interceptor Ditch, Woman Creek, and South Walnut Creek and at one or more reference areas (Table 2-1 and Figure 2-1). No samples will be collected on the ground water seep areas within OU No. 2, or at the most downstream stations on Woman and South Walnut Creeks, because there is not enough water flow or depth for the samplers. Instead, qualitative samples will be taken from natural substrates at these locations.

Periphyton samplers will be set for two full colonization periods, essentially corresponding with high (late Spring-early Summer) and base (late Summer-early Fall) flow conditions. Since there is substantial interaction between the surface and ground water systems at the Rocky Flats Plant, the influence of contaminant releases from the source areas may vary considerably under high and base flow conditions.

Field Methods

Two artificial substrate samplers holding six plexiglass slides will be placed at each sampling location at the beginning of the exposure period. The sampler consists of an anchor and float assembly with the plexiglass slide holder suspended in the water column about 30 cm below the water surface. Co-located samplers will be located at each station and placed in similar habitats within a 30-meter stream section. At two stations, the second sampler will be used for duplicate samples. At the remaining stations the second sampler will be used if additional biomass is needed for bioaccumulation (tissue analysis) or if the primary sampler is lost.

Flow conditions and other physical and biological characteristics of the sampling station will be documented in the field log when the sampler is set and picked up. Field instruments will be used to measure water quality parameters (temperature, pH, conductivity, and dissolved oxygen) at the beginning and end of the exposure period (14 days minimum) and at three-day intervals during the exposure period. Other field measurements may be taken where visual evidence suggests contamination. Qualitative observations regarding the occurrence of periphyton, filamentous algae, fish and amphibians, and slimes on natural substrates will be recorded in the field log.

Sample Preparation/Analysis

Periphyton material will be collected from different slides for identification and enumeration, biomass determinations, and chlorophyll-a/phaeophytin-a concentrations. The slides will be selected randomly.

For identification and enumeration, all periphyton will be scraped from both sides of a slide and transferred to a sample vial with distilled water. The sample will be diluted, preserved, and allowed to settle in a sedimentation cylinder for approximately 12 hours. The sample will then be resuspended in 200-1,000 milliliters (mL) of water, depending on the volume of the sample, and the organisms will be identified to the genus level and counted at about 320X magnification.

For biomass determinations, the periphyton growth from one or two slides will be scraped into a preweighed crucible. The sample will be dried at 105°C for 12 hours (or until a constant weight is obtained), weighed, and then ashed in a muffle furnace at 600°C for one hour and weighed again. The difference between the two weights is the ash-free dry weight (organic weight) of the sample.

Periphyton from both sides of a slide will be scraped into a container and placed in a 90 percent acetone solution for chlorophyll/phaeophytin analyses. The sample extract (about 20 to 50 mL) will be homogenized, steeped for 12 hours, and centrifuged. The optical density of the extract at 750 and 630 nanometers (nm) will be determined by spectrophotometer, and the concentration of chlorophyll-a will be recorded. The concentration of phaeophytin-a will be determined from optical density readings at 633 nm before and after acidification.

For tissue analysis (bioaccumulation), six composite samples will be collected, placed in glass vials, and stored on ice. The composite samples will be collected from the following locations:

Sample 1	SW-70 and SW-54 (SID)
Sample 2	SW-32A and SW-28 (Woman Creek)
Sample 3	Ponds C-1 and C-2 (Woman Creek)
Sample 4	SW-23 and SW-24 (South Walnut Creek)
Sample 5	Ponds B-4 and B-5 (South Walnut Creek)
Sample 6	SW-C (Reference Area)

Periphyton will be scraped from six to nine slides at each sample station and transferred to glass vials using distilled water. Samples will be stored on ice in the field, then composited in the field laboratory. Periphyton samples will be shipped fresh (on ice) to the analytical lab within 48 hours of collection or frozen and shipped at a later time.

Ecological Endpoints

Periphyton samples will be analyzed for cell counts, genera, species diversity, biomass, and chlorophyll-a and phaeophytin-a concentrations. The standing crop (biomass) at the end of the 14 day minimum exposure period will be an estimate of colonization rate. Chlorophyll/phaeophytin concentrations will provide an estimate of productivity. Proportions of pollution-sensitive and pollution-tolerant genera will be reported.

Equipment

The field equipment needed for periphyton sampling includes the following:

- Field data sheets for recording site descriptions, water quality data, flow conditions, etc., chain of custody forms
- Periphyton samplers (including slides) with anchors and floats
- Boots and waders
- Boat and oars, anchor and life preservers

- Sample containers, labels, preservatives
- Water quality field instruments
- Cooler and ice
- Decontamination equipment
- Instrument calibration standards
- Spare slide racks with extra slides
- Distilled Water
- Containers for water and sediment samples
- Preservative (37% formalin)

2 4 1 2 Benthic Macroinvertebrates

Benthic macroinvertebrates are the most common fauna used in ecological assessments of contaminant releases or pollution discharges. They are defined as the aquatic invertebrates that are large enough to be seen without magnification and capable of being retained by a U S Standard No 30 sieve [(0.595 millimeters (mm) openings)]. Benthic macroinvertebrates will be collected from all aquatic sampling stations. In cases where the habitat does not allow quantitative sampling, qualitative samples will be collected with dip nets and by grab samples of substrate and coarse particulate organic matter (CPOM, e.g., leaves, twigs, and plant debris). Field sampling procedures will conform to SOP 5.2, Ecology 5.0 (EG&G, 1991d).

Location/Frequency

Benthic macroinvertebrates samples will be collected at all 19 stations used for quantitative aquatic sampling (Table 2-1 and Figure 2-1). Macroinvertebrates will be sampled quantitatively in the late Spring-early Summer and late Summer-early Fall. The intent is to sample under high flow and base flow conditions. The creek and pond sample stations will be defined as a 50-meter segment of the creek or a 50-meter section of the pond shoreline. In the ponds, samples will be taken at depths less than two meters deep, generally in the inlet or discharge areas of the pond.

Field Methods

Two types of benthic samplers will be used to sample riffle/run areas of creeks and pool habitats at creeks, ponds, and seeps. A Surber sampler with a 1 square-foot [0.09 square meters (m²)] frame and

352 micrometer mesh net will be used to sample shallow creek stations (riffle/run areas) where the substrate is primarily sand/gravel and flow is sufficient to carry the macroinvertebrates into the net. Triplicate samples will be taken within the 50-meter creek segment, working upstream. Each replicate sample will be transferred directly into a plastic sample container and preserved in 10 percent formalin.

At pool habitats in creeks, and at the pond and seep stations, triplicate samples will be collected with an Ekman grab sampler. A pole mount or remote messenger sampler will be used with the Ekman sampler at most or all sample stations, providing a more uniform depth sample. A rope-suspended sampler triggered with a messenger will be used at stations that are too deep for the pole-mounted sampler. Each triplicate sample will be transferred from the sampler to a field wash bucket with a No 30 sieve mesh or smaller, washed thoroughly, and then placed into a sample container and preserved. Large rocks or twigs can be discarded during the washing process after organisms are hand picked or washed into the bucket with a water spray.

Qualitative samples of CPOM will be collected at stations where there are substantial quantities of plant debris. Several handfuls of leaves, twigs, and/or grass will be placed into the sample container and labeled as a qualitative CPOM sample. The benthic organisms will be picked from this debris in the laboratory and the number of individuals in each Functional Feeder Group (EPA, 1989a) will be recorded. Organisms in these samples may not be identified to genera because the principal objective is to assess the proportion of scrapers, filterers, and shredders at the sample station.

Benthic macroinvertebrates will be collected at two downgradient stations on Woman Creek and South Walnut Creek for tissue analysis. This will be done to determine if inorganic and radionuclide contaminants may be accumulating in the tissue of the dominant species. Samples will be collected with dip nets, kick nets, and/or Surber and Ekman samplers. Sampling will continue until a sufficient biomass of some of the dominant species are obtained for laboratory analysis. The samples may be washed in the field, then placed in sample containers and kept on ice. The organisms will be picked from the sample in the laboratory and kept at or near 4°C. Samples will be shipped to the analytical laboratory within 48 hours of collection or frozen and shipped at a later time.

The flow conditions and other physical and biological characteristics of the sampling station will be documented in the field log. Field instruments will be used to collect basic water quality data. Water quality and sediment samples will also be collected. Qualitative statements regarding the occurrence of periphyton, algae, amphibians, and fish will be recorded. All samples will be numbered and labeled as they are collected.

Sample Preparation/Analysis

Benthic macroinvertebrate samples will be processed in the laboratory by rinsing the sample in fresh water (U S Standard No 60-mesh screen) and transferring the sample to a shallow white tray. Benthic organisms will be separated from the debris with forceps, using a table-mounted magnifier, and placed into sample vials of 10 percent formalin. The samples will be analyzed by identifying the organisms to genus (with some exceptions such as chironomids) and counting the number of individuals in each taxon. Identification and enumeration will be made using dissecting microscopes.

Ecological Endpoints

Benthic macroinvertebrate samples from each station will be analyzed for genera present, species diversity, total number of organisms by taxa, and the proportion of pollution-tolerant or pollution-sensitive taxa. The relative abundance of scraper, filter collector, and shredder Functional Groups will also be determined (EPA, 1989a).

The data from quantitative samples will be used to determine macroinvertebrate density (standing crop), taxa richness, species diversity, ratio of scraper and filtering collector functional feeding groups, ratio of pollution-tolerant and pollution-sensitive taxa, and community similarity indices.

Equipment

The field equipment required for benthic macroinvertebrate sampling includes the following:

- Field data sheets, chain-of-custody forms
- Field logbook
- Surber sampler with 352 microns (μ) mesh net
- Ekman sampler
- Benthic wash buckets with No 30 sieve (or smaller)
- Dip nets
- Boots and waders
- Sample containers, labels, and preservatives
- Boat and oars, anchor and life preservers
- Water quality field instruments

- Cooler and ice
- Decontamination equipment
- Instrument calibration standards
- Preservative (37% Formalin)
- Tape Measure
- Brush (with soft plastic bristles)
- Forceps
- Squirt bottle
- Plastic tub (50 cm square or larger, for use with Surber or Cone samplers)
- Littoral rinse bucket (for use with Ekman Dredge)
- Distilled H₂O

2 4 1 3 Fish

Fish communities will be sampled at four creek stations within OU No 2, at a reference station on Rock Creek or the upper end of Woman Creek, and at ponds along Woman Creek and South Walnut Creek (Table 2-1 and Figure 2-1) Fish will be collected by electroshocking from similar sized creek segments or shoreline areas, using procedures that will yield catch-per-unit-effort results All fish will be identified and counted Water quality data will be collected in association with the sampling effort The physical characteristics of each sampling location will be documented to assess the influence of physical features on fishing success and the types and abundance of fish present Field sampling procedures will conform to SOP 5 3, Ecology 5 0 (EG&G, 1991d)

Location/Frequency

Fish communities will be sampled at eight stations within OU No 2 and at one or more reference stations (Table 2-1) The two ponds on Woman Creek (C-1 and C-2) and the two lower ponds on South Walnut Creek (B-4 and B-5) will be sampled The upper three ponds on South Walnut Creek will not be sampled because they are off-channel ponds used to control spills (B-1 and B-2), or to contain and control surface runoff and the discharge from the sanitary wastewater treatment plant at the Rocky Flats Plant (Pond B-3) Since flow along Woman Creek downgradient of Pond B-3 goes through Ponds B-4 and B-5 sampling of these two ponds should provide adequate assessment data

Since there are very limited running water habitats along South Walnut Creek no creek stations will be sampled. On the South Interceptor Ditch and Woman Creek, sample stations will be located at the upper and downgradient areas of the operable unit (Table 2-1 and Figure 2-1). Sampling results from the four on-site creek stations will be compared to the reference station off site.

The sample stations for fisheries work will be the same 50-meter creek segments or 50-meter shoreline areas used for benthic sampling. Fish will be collected from all stations during the late Spring-early Summer period and again in late Summer-early Fall. All fish will be released back to the creek or pond except for a limited number of reference specimens, small fish that cannot be identified in the field, and individuals collected for tissue analysis. Precautions will be taken so that the sampling effort itself does not produce an impact on fish populations. Fish kept for identification or reference will be preserved in 10 percent formalin, and fish kept for tissue analysis will be put on ice.

Field Methods

Fish will be collected from the 50-meter stream segment by setting blocknets at each end of the station and making two or three collection passes with a backpack or electroshocker. Fish will be removed from the creek with long-handled dip nets and placed in live tanks. The mesh size on the dip nets will be determined during the qualitative field survey effort so that adult fish and most juveniles are retained in the net. A standard sampling time of 20 to 30 minutes will be established while sampling the first two stations. The same shocking time will be used at all stations. While the stream is still blocked, short seines or dip nets will be used after shocking to check deep holes and shoreline pockets.

Fish samples will be processed immediately after shocking is completed. All fish will be identified, counted, and measured (total length to the nearest mm). Dominant species will also be weighed. As stated above, most fish will be released back to the creek. Data will be recorded on standard field data sheets. Small individuals may be kept for identification in the laboratory. At the pond stations, fish will be collected by shocking along 50-meter portions of the shoreline. Since it is impossible to use block nets for pond sampling, repeated passes along the same shoreline segment would be unproductive, so several 50-meter areas may be sampled if fishing success is poor. Pond sampling may be more productive during the late afternoon or evening.

The physical characteristics of each sampling station will be described in the field log and conditions which may influence catch success will be recorded. Basic water quality measurements will be taken with field instruments at each sampling station.

Sample Preparation/Analysis

Fish samples will be processed in the field, allowing most fish to be released alive. Fish specimens retained for reference or identification will be preserved and labeled. Fish kept for tissue analysis will be kept on ice in labeled plastic bags and processed within 24 hours of collection. If possible, minnows and/or sunfish will be collected for tissue analysis at all stations. Large fish of other species, such as bullheads, will be kept if more biomass is needed for analysis. The larger fish will be filleted and the right and left fillets will be wrapped separately in aluminum foil, labeled and frozen. Catfish and bullheads will be skinned. Each fish will be divided along the backbone so that the right and left sides can be wrapped and frozen separately. Smaller fish selected for tissue analysis will be cleaned and frozen whole. Right and left fillets can be used as duplicate samples and/or submitted to different laboratories for inorganic and radionuclide analyses.

Ecological Endpoints

All fish will be identified, counted, and measured. The fisheries data will be analyzed for relative abundance, catch-per-unit-effort statistics, length-frequency histograms, and the relative proportions of herbivorous, carnivorous, or omnivorous species.

Equipment

The field equipment required for fisheries sampling includes the following:

- Field data sheets, chain-of-custody forms
- Field logbook
- Backpack electroshocker
- Measuring board and scales
- Boots and waders
- Sample containers, labels, and preservatives
- Boat and oars, anchor and life preserver
- Water quality field instruments
- Cooler and ice
- Decontamination equipment

- Instrument calibration standards
- Fish Identification keys and hand lens
- Seines (beach seine, kick seine)
- Reinforced dip-nets
- Small dip-nets
- Rubber Gloves
- 5-gallon bucket or equivalent to be used as line well

2 4 2 Terrestrial Ecosystems

The FSP for terrestrial communities is directed at sampling grasslands, wetlands, small mammals, invertebrates, and roots/microbes at selected locations at the source areas and stations east of the source areas. A reference area or areas selected for comparative studies will be sampled for similar components and parameters. The stations selected for terrestrial sampling are shown in Figure 2-2, while the sampling program is summarized in Table 2-2. The station location or the selection of the component being sampled may be modified to be consistent with the results of the Spring qualitative survey and to correspond to surficial sampling locations.

2 4 2 1 Grassland Vegetation

The grassland community at the reference and test areas will be sampled for plant species, cover, and productivity using standardized quadrats. These parameters give the best indication of the structure and function of dryland vegetation. A preliminary field reconnaissance of the site did not reveal significant areas of other vegetation types. There are no shrubland or woodland types of a size sufficient to sample. The isolated shrubs or single trees will be noted or sampled within the quadrats selected for grassland sampling. Field sampling procedures will conform to SOP 5 10, Ecology 5 0 (EG&G, 1991d).

Location/Frequency

Grassland vegetation will be sampled at the 11 stations shown on Figure 2-2. These will be staked and located to represent the grassland type in the vicinity of the location selected. Sample locations will be determined during the qualitative field surveys by ground truthing and with the use of maps and aerial photographs. The same locations will also be used for sampling small mammals, roots, and invertebrates. Within the sampling area, one-square-meter plots for cover and quarter-square-meter

TABLE 2-2

**TERRESTRIAL FIELD SAMPLING PROGRAM FOR
VEGETATION, SMALL MAMMALS, AND WETLANDS
OPERABLE UNIT NO 2**

Component	Parameter	Sampling Period	Station
Grassland	Cover by species Productivity Tissue analysis	Early Summer Late Summer	TS-1 to TS-11
Small Mammals	Species Density Tissue analysis	Early Summer Late Summer	TS-1 TS-2 TS-6 TS-9 TS-10
Roots Microbes	Tissue analysis Depth & density Biomass	Late Summer	TS-1 to TS-7 TS-9
Invertebrates	Species Tissue analysis	Early Summer	TS-1 to TS-11
Wetlands	Species Dominance Tissue analysis	Late Summer	WS-1 to WS-9

clipping plots will be located using a random stratified method. The area will be gridded and a spot on the grid selected using a random number generator. Quadrat locations may be rejected for being disturbed or not representative of the vegetation in the area.

Grassland will be sampled during two periods: an early season sample during late Spring-early Summer and a late season sample during the late Summer. Cool-weather grasses and early-season forbs will be sampled during the first sampling period. Warm-season grasses and late-season forbs will be sampled during the latter period.

Field Methods

Two sizes and types of quadrats will be used: one-square-meter plots for cover and quarter-square-meter plots for current season productivity (clipping plots). In the one-square-meter plots, the cover of each plant species will be visually estimated to the nearest percent and notes made on condition and phenology. The quarter-meter plots will be clipped according to the current season's growth by species or type of species and bagged for dry weight and tissue analysis. The number of quadrats for both cover and productivity will be determined by a sample adequacy formula. There will not be less than 15 quadrats for each type.

Sample Preparation/Analysis

The cover quadrats will be analyzed for species composition and cover, and the frequency and dominance (importance) values derived. The sample clipped for productivity will be oven-dried to a constant weight and weighed. Additional samples will be collected and analyzed for tissue concentrations of a standard list of inorganic chemicals and radionuclides. The analytical parameters are listed in Section 2.5.4.

Ecological Endpoints

The grassland quadrat sample will provide species composition, cover, productivity, diversity, and structure of the terrestrial ecosystems. Tissue sample analysis will provide information on concentrations of contaminants in vegetation as an indication of bioaccumulation.

Equipment

Equipment to be used for grassland sampling includes

- Field forms (for recording cover and clipping plots data), labels, chain-of-custody forms
- Metric rulers
- One- and 0 25-meter-square frames
- Stainless Steel Scissors
- Paper sacks and indelible marker
- Plastic bags
- Cooler and ice
- Glass sample containers
- Field identification guide
- Decontamination equipment

2 4 2 2 Small Mammals

Small mammals will be trapped live at the reference areas and at some of the same locations as the grassland plots. Small mammals, particularly microtines, will be trapped because they are primary consumers of vegetation and form the basis for the link to the higher levels in the food chain leading to top carnivores. Mice and ground squirrels will be trapped because they live on and in the soil, they may be directly exposed to contaminants. Field sampling procedures will conform to SOP 5 6, Ecology 5 0 (EG&G, 1991d).

Location/Frequency

Small mammals will be trapped at 5 of the 11 sampling locations shown on Table 2-2. These locations may be modified, based on results of the qualitative field surveys conducted in the late Spring. There will be two trapping periods, the first in mid-June for early season densities, and one in late August to determine changes in densities from the season's reproduction.

Field Methods

Two small grids of live traps will be laid out in five rows of five traps each at 5-meter intervals for a total of 50 traps or 25 traps per grid. Traps will be baited with rolled oats, cornmeal or peanut butter. The traps will be run for four consecutive nights at four-hour intervals using standard procedures for trapping protocol. Animals trapped will be recorded for species, weight, sex, and breeding condition and examined for the presence of tumors and ectoparasites. Prior to release, each captured animal will be marked with a pelage dye for recapture data and population estimates. At the end of the trapping period, a number of individual animals will be collected and preserved for tissue analysis. A representative sample will be determined from the trapping results. Animals selected for tissue or organ analysis will be asphyxiated by nonchemical, manual suffocation, placed in plastic bags, and stored on dry ice for transport to the laboratory for analysis.

Sample Preparation/Analysis

The animals will be prepared according to laboratory procedures established for the type of analysis to be conducted. Animals selected for organ analysis will be dissected prior to tissue analysis.

Ecological Endpoints

The small mammal populations will be analyzed for species, density, and reproductive success. These parameters will be indicative of the condition of this important trophic level.

Equipment

Field equipment that will be used for small mammal trapping includes

- Field data sheets for recording sampling information, labels, chain-of-custody forms
- Sherman or equivalent live traps
- Plastic bags
- Field scales in grams to the nearest gram
- Cooler and dry ice

- Bait (rolled oats, cornmeal, or peanut butter)
- Stiff brush and squirt bottle

- 25-m or 5-m fiberglass tape measure
- Food coloring (three colors)
- Glass sample jars
- Field identification guide
- Field notebook
- Metafane

2 4 2 3 Roots and Microbes

Roots for tissue analysis will be collected in hand-dug trenches to a depth (probably about 0.5 meter) to be determined during the qualitative surveys of rooting depths and density. Collection will occur once during the late Summer growing season at the station indicated in Figure 2-2 and listed in Table 2-2. Roots will be collected from the sides of the trench for the equivalent of about 100 grams of root material from incremental depths of 10 cm to the bottom of the trench. They will be placed in plastic bags, stored in a cooler with ice, and transported to the laboratory for tissue analysis. The tissues will be analyzed for the contaminants listed in Section 2.5.4. The ecological endpoints for the root tissue sample analysis is to determine possible amounts of transport to vegetation from root uptake of contaminants. Microbial biomass will be sampled using a chloroform fumigation and extraction method on known volumes of soil.

2 4 2 4 Invertebrates

Invertebrates, mostly insects, will be collected at all vegetation sampling locations by the use of sweep nets. Sweeps will be accomplished by making approximately 20 strokes at the top of the vegetation canopy. The material caught in the net will be placed in killing jars, stored in vials, and transported to the laboratory for analysis. Ground-dwelling arthropods will be picked up by hand and handled in the same manner as invertebrates caught in the sweep nets. The ecological endpoints of the invertebrate sampling is a compilation of the common species in this ecosystem component. Field sampling procedures will conform to SOP 5.9, Ecology 5.0 (EG&G, 1991d).

2 4 2 5 Wetlands

Wetlands will be sampled because they are an important and productive vegetation type although small in size and extent. The wetlands at OU No. 2 grow around seeps on the slopes below the source areas and along drainages and ditches. Wetlands will be characterized for location, size and condition, and

sampled in late Summer for dominant species present. Samples will be taken of major plant species for tissue analysis. The growing shoots will be clipped and handled in the same manner as the grassland samples. The ecological endpoint of the wetland sampling is a determination of whether wetland plant tissues bioaccumulate contaminants in surface water from underground springs and seeps. Field sampling procedures will conform to SOP 5.10, Ecology 5.0 (EG&G, 1991d).

2.5 QUALITY ASSURANCE/QUALITY CONTROL

The basic QA/QC protocols for the ecological assessment at OU No. 2 are incorporated into this Environmental Evaluation Work Plan (EEWP) and in existing QA/QC documents for the OU No. 2 RFI/RI and the ER Program at Rocky Flats Plant. Also, many of the OU-specific QA/QC protocols will be presented in project documents that will be prepared prior to implementing the field sampling. For example, DQOs and the basic QA/QC protocols for the field sampling will be presented in an OU-specific QAA. Also, sample management and waste management protocols, as well as details of laboratory analytical requirements, will be prepared after the EEWP is approved. This section of the FSP addresses some of the QA/QC issues and indicates the general QA/QC protocols that will be developed and used for the EE.

The EE will be implemented under the QAPjP and the project-specific QAA. The QAA is consistent with the draft QAPjP prepared for the ER Program at the Rocky Flats Plant (EG&G, 1990b). The QAA will describe the QA/QC policy and protocols necessary to achieve the required DQOs for OU No. 2. Development of the DQOs has been initiated and these will be incorporated into the QAA or a companion document.

The QAPP and QAA program will address such items as

- Project organization
- Authorities and responsibilities
- QA objectives
- Sampling and analysis procedures
- Custody of samples
- Analytical procedures
- Data validation reporting
- Internal quality control

- Data assessment procedures
- Quality assurance reports
- Auditing

This section of the FSP addresses some of the QA/QC issues and indicates the general QA/QC protocols that will be developed and used for the EE

2 5 1 Sample Documentation

Standard procedures will be developed to document sampling activities and conditions. Standard procedures will also be used to label and track field samples. Bound field logbooks will be used to document field activities and sampling conditions. Standardized data sheets will be used for the different sampling activities so that complete data records are maintained. The sampling team leader and team members will be recorded for each day. Entries in the logbook and data sheets will allow the sampling team leader to recreate sampling details at a later date if necessary. All sampling locations will be described.

A sample management plan will be developed to control sample labeling and provide a numbering system to track individual samples in the field and laboratories, and in the data management system. Chain-of-custody procedures for both chemical and biological samples will be established. The sample management plan will be integrated with the ongoing RFI/RI activities at OU No. 2.

2 5 2 Equipment Calibration and Checks

All equipment will be checked prior to field work, on a daily basis when necessary, to assure that all equipment components are in place and that the equipment is operating properly. Manufacturer's operating manuals and calibrating procedures will be followed for field instrumentation (e.g., pH meters and photoionization detectors). Calibrations for the appropriate instruments will be made on a daily basis. The field team will include operators trained in the use of each instrument, and these operators will check the equipment periodically during the day to determine that the instruments are working properly. A system for flagging defective equipment to preclude its use will be developed.

Equipment lists will be maintained for all sampling activities so that field crews are adequately and completely equipped. Also, only qualified operators will be used to operate field instruments and equipment such as fish electroshockers.

2 5 3 Health and Safety/Waste Management

Health and Safety Plans (HSPs) will be prepared for each sampling activity or field effort. Field crews will be informed of potential hazards associated with the site area and with sampling operations. The HSP will address both physical and chemical/radiological hazards and include medical emergency protocols and contacts.

A waste management plan will be developed to describe procedures required to decontaminate equipment and personnel before and after sampling activities. The plan will describe procedures for handling potentially toxic or radioactive waste appropriately. Further, the plan will describe waste characterization/classification protocols and waste handling and segregation procedures. The plan will also address packaging and labeling of wastes and transferring sample-generated wastes to the proper on-site storage or disposal areas.

A Health and Safety Plan, needed to meet the minimum requirements identified in the Rocky Flats Plant ER Program Site Health and Safety Plan Workbook (EG&G, 1990b), will be developed for the EE prior to the commencement of any field investigations or field sampling. The Workbook addresses the following health and safety requirements:

- Safety and Health Assessment (chemical, radiological, biological, and physical hazards)
- Training
- Personal Protective Equipment (PPE)
- Site Monitoring
- Decontamination
- Emergency Response
- Confined Space Entry
- Spill Containment

Because OU No. 2 contains 18 solid waste management units (SWMUs) [or individual hazardous substance sites (IHSSs)], personnel involved in the actual field work and sampling will be required to have 40 hours of Occupational Safety and Health Administration (OSHA) training. They will be instructed in the use of PPE appropriate for the level of hazardous substances expected to be found. The HSP will also address decontamination procedures for personnel and equipment.

In addition, all personnel assigned to field activities at OU No 2 will receive two hours of health physics training. This training will address the types of radionuclides expected at the unit and the potential effects of human exposure. Appropriate precautions and protective measures for those potentially exposed to radiological hazards will be incorporated into the HSP.

2.5.4 Sample Handling and Analytical Protocols

Sample management plans and laboratory analytical protocols will be developed to establish standard procedures for handling, preserving, and shipping samples. The protocols will also address methods of communicating analytical requirements to the laboratories.

For the bioaccumulation study, tissue samples from terrestrial and aquatic organisms will be kept on ice and shipped to the laboratory within 24 to 48 hours of collection, or frozen and shipped to the laboratory at a later time. Tissue samples will be analyzed for the inorganics (metals) and radionuclides listed in Table 2-3. These inorganic elements and radionuclides have been detected at the 903 Pad, Mound, and East Trenches Areas during the Phase I RFI/RI. The holding times, preservation methods, and approximate sample sizes required are presented in Table 2-4. Metals will be determined by inductively coupled argon plasma spectroscopy (ICP) or graphite furnace atomic absorption spectroscopy (GFFA). GFFA is required to attain the lower detection limits needed to assess risks for the more toxic and/or carcinogenic inorganics. The detection limits will be established during development of the QAA and DQOs.

Tissue samples will not be analyzed for organics. The principal organic contaminants at OU No 2 are volatiles, and these compounds will normally volatilize fairly quickly from surface water, air, and surficial soils that are the most common exposure points for living organisms. Also, the laboratory protocols for tissue digestion and analysis frequently do not provide good quality consistency or reproducible results for volatile organics unless extreme care is taken in handling and processing the samples. Therefore, bioaccumulation studies will be limited at present to inorganics and radionuclides.

The sample management plan and laboratory analytical protocol document will specify the type and number of QA/QC samples required in the field and in the laboratory. For example, duplicate field samples will normally be collected at a rate of at least one duplicate sample per ten field samples. Various types of field blanks will also be collected or prepared to verify equipment decontamination or check on extraneous sources of contamination. The QA/QC samples required for laboratory processing (e.g., laboratory duplicates, spiked samples, and blanks) will be specified in the laboratory analytical protocols.

2 5 5 Statistical Analysis and Procedures

Standard statistical methods and procedures will be used to analyze data collected in the quantitative sampling program. Where appropriate, data will be analyzed for the statistical parameters of means, variances, and standard deviation to determine precision of values. Normally distributed data will also be analyzed for variances and correlation coefficients or regression analysis to determine, for example, if contaminant concentration in tissue is related to media contaminant concentration. Significant differences in paired samples between locations or sampling periods will be established, such as comparisons between reference areas and the test area sample data. Sample adequacy formulae will be used to determine if the number of samples is adequate based on mean, variance, and the level of accuracy needed. Since much of the data used to characterize the biological parameters are simply descriptive, values such as the arithmetic mean, maximum, and minimum will be reported for many samples.

TABLE 2-3

**ANALYTICAL PARAMETERS FOR BIOACCUMULATION
STUDY TISSUE ANALYSES, OU NO 2**

Metals		Radionuclides
Aluminum	Magnesium	Uranium 223, 234, 235, 238
Antimony	Manganese	Americium 241
Arsenic	Mercury	Plutonium 239, 240
Barium	Molybdenum	Strontium 89, 90
Cadmium	Nickel	Tritium
Calcium	Potassium	
Chromium III	Selenium	
Chromium IV	Silver	
Copper	Sodium	
Iron	Strontium	
Lead	Vanadium	
Lithium	Zinc	

TABLE 2-4

**HOLDING TIMES, PRESERVATION METHODS,
AND SAMPLE CONTAINERS FOR BIOTA SAMPLES**

Samples for Metal Analyses	Maximum Holding Time From Date Collected	Preservation Method	Container	Approximate Sample Size*
Terrestrial Vegetation				
Metals Determined by ICP**	6 mos	Freeze and ship with dry ice	Paper bag inserted into plastic bag and sealed	25g
Metals Determined by GFAA+	6 mos	Freeze and ship with dry ice	Paper bag inserted into plastic bag and sealed	25g
Hexavalent Chromium	24 hrs	Freeze and ship with dry ice	Paper bag inserted into plastic bag and sealed	25g
Mercury	29 days	Freeze and ship with dry ice	Paper bag inserted into plastic bag and sealed	5g
Periphyton and Benthic Macroinvertebrates				
Metals Determined by ICP	6 mos	Freeze and ship with dry ice	Plastic	25g
Metals Determined by GFAA	6 mos	Freeze and ship with dry ice	Plastic	25g
Hexavalent Chromium	24 hrs	Freeze and ship with dry ice	Plastic	25g
Mercury	28 days	Freeze and ship with dry ice	Plastic	5g

Sheet 1 of 2

TABLE 2-4 (Continued)

**HOLDING TIMES, PRESERVATION METHODS,
AND SAMPLE CONTAINERS FOR BIOTA SAMPLES**

Samples for Radionuclide Analyses	Maximum Holding Time From Date Collected	Preservation Method	Container	Approximate Sample Size
Terrestrial Vegetation				
Uranium-223, 224, 235, 238 Americium-241 Plutonium-239, 240 Tritium Strontium-89, 90	6 mos	Freeze and ship with dry ice	Paper bag inserted into plastic bag and sealed	100-500g
Periphyton, Benthic Macroinvertebrates, and Fish				
Uranium-223, 224, 235, 238 Americium-241 Plutonium-239, 240 Tritium Strontium-89, 90	6 mos	Freeze and ship with dry ice	Plastic	100-500g

* Sample size may vary with specific laboratory requirements

** ICP = Inductively Coupled Argon Plasma Emission Spectroscopy

+ GFAA = Graphite Furnace Atomic Absorption Spectroscopy

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ATTACHMENT 3.0
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3 0	EXAMPLE TOXICOLOGICAL PROFILE 1,1-DICHLOROETHANE
3 1	INTRODUCTION
3 1 1	Environmental Toxicity
3 1 2	Human Toxicity
3 1 3	Carcinogenicity
3 2	REFERENCES

GLOSSARY OF ACRONYMS

bw	body weight
CNS	Central Nervous System
EPA	U S Environmental Protection Agency
IARC	International Agency for Research on Cancer
log K _{ow}	log of octanol/water partition coefficient
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mg/m ³	milligrams per cubic meter
mm	millimeter
NCI	National Cancer Institute
NOEL	No Observable Effect Level
ppm	parts per million

EXAMPLE TOXICOLOGICAL PROFILE 1,1-DICHLOROETHANE

3 1 INTRODUCTION

The chlorinated ethanes are produced in large quantities and are used for production of tetraethyl lead and vinyl chloride, as industrial solvents, and as intermediates in the production of other organochlorine compounds. All of the chlorinated ethanes studied have been found to be mildly toxic, with toxicity increasing with the degree of chlorination. Density and melting point also increase with halogen substitution. Conversely, both water solubility and vapor pressure decrease with halogen substitution.

1,1-dichloroethane has the molecular formula $C_2Cl_2H_4$ and a molecular weight of 98.96. Also known as ethylidenechloride or ethylenedichloride, pure 1,1-dichloroethane has a vapor pressure of 182 millimeters (mm) mercury Hg, a water solubility of 5,500 milligrams per liter (mg/l) (Archer, 1979) and a log K_{ow} of 1.79 (Valvani, et al, 1981). Based on these data, this compound would be expected to partition into the water column in aquatic ecosystems, rather than adsorb to suspended particulates. It has an estimated half-life in water of one to five days and a half-life in air of one and one-half months (Callahan, et al, 1979), no half-life value for 1,1-dichloroethane in soil could be located in the available literature. However, evaporation is expected to be the predominant loss mechanism from the soil surface. The half-life for soil evaporation should be longer than its evaporation half-life from water. In subsurface soil, the loss of 1,1-dichloroethane through biodegradation is expected to be insignificant (Wilson, et al, 1983). Therefore, 1,1-dichloroethane may persist in soil and is expected to be removed primarily through leaching into ground water.

Halogenated hydrocarbons have been identified in 80 domestic water supplies by Symons, et al (1975). 1,1-dichloroethane was among the compounds identified in finished water of several metropolitan areas (Coleman, et al, 1976, Kopfler, et al, 1976).

3 1 1 Environmental Toxicity

Few animal studies have been conducted with 1,1-dichloroethane. In a study conducted by Larson, et al (1955), three dogs were intubated with 200 milligrams per kilogram (mg/kg) body weight (bw) for six days/week for eight weeks in order to observe the effects on the adrenal gland. All three animals survived and none had significant histopathology of the adrenals. Other parameters of toxicity were not reported. Rats given 1,1-dichloroethane in a corn oil carrier via gavage exhibited depressed body weights at dosages greater than 1,000 mg/kg bw (NCI, 1978). Males appeared susceptible to lower

doses than females. However, these studies were considered too limited in their assessment of toxicity criteria to be useful in risk assessment.

Of several species tested, cats appeared to be the most sensitive to inhaled 1,1-dichloroethane. Blood urea nitrogen levels were immediately elevated during post-exposure and peaked at approximately three times the normal level. Histopathological examination of the cats revealed renal tubular dilation and degeneration, indicating kidney damage (Hofmann, et al., 1971). Based on data from this study and another by Torkelson and Rowe (1981), a no observable effect level (NOEL) of 500 parts per million (ppm) [2,025 milligrams per cubic meter (mg/m³)] can be suggested for subchronic exposure in rats, cats, guinea pigs, rabbits, and dogs.

The only study of chronic oral toxicity to 1,1-dichloroethane was reported in the NCI carcinogenicity assay (NCI, 1978), in which 50 male and 50 female rats and mice were intubated with the compound in a corn oil carrier. Treatments were administered for five days/week for three weeks, followed by one dose-free week and three additional treatment weeks over the 78-week treatment period. All groups of male and female rats exhibited a hunched appearance, abdominal urine stains, labored breathing, wheezing, and nasal discharge. Although there were no definitive signs of 1,1-dichloroethane toxicity in physical appearance or behavior of the mice, survival of both males and females was adversely affected.

In Schwetz, et al. (1974), female rats were exposed to 0, 3,800, or 6,000 ppm 1,1-dichloroethane via inhalation for seven hours/day on days 5 to 15 of gestation. The highest dose resulted in an increased incidence of delayed ossification of sternebrae in the newborn rats.

3.1.2 Human Toxicity

At one time, 1,1-dichloroethane was used as an anesthetic, with an anesthetic pressure of 0.026 atmospheres, -105,000 mg/m³ (Miller, et al., 1965). The ability of the compound to induce cardiac arrhythmias caused discontinuation of its use as an anesthetic (Browning, 1965). It is probable that human exposure to sufficiently high levels of 1,1-dichloroethane would cause central nervous system (CNS) depression and respiratory tract and skin irritation, as is the case in exposure to many other chlorinated aliphatics. Although the EPA (1980, 1983) stated that no information was available on unusual sensitivity of any groups to any of the chlorinated ethanes, it was suggested that individuals with liver insufficiency or exposure to other hepatotoxins may be at increased risk. Presumably, individuals with impaired renal function may also be unusually sensitive to exposure to 1,1-dichloroethane. In general, there is a paucity of information regarding the impact of this compound to human health.

3 1 3 Carcinogenicity

In the 1978 National Cancer Institute (NCI) carcinogenicity assay, female rats demonstrated a significant dose-response relationship in the incidence of hemangiosarcoma. However, male rats showed no significant change in neoplastic incidence that was related to the 1,1-dichloroethane compound. Mammary adenocarcinomas were also considered significant in the females, using the Cochran-Armitage test for linear trend in proportions. However, significance was not demonstrated using the Fisher Exact test. In female mice, the Cochran-Armitage test showed a positive dose-response relationship in the incidence of benign endometrial stromal polyps that was coincident with results of the Fisher Exact test. NCI concluded that this evidence suggested the possible carcinogenic potential of 1,1-dichloroethane but deemed it inconclusive.

Weisburger (1977) reviewed NCI's bioassays of several halogenated aliphatics and noted that 1,1-dichloroethane and tetrachloroethylene both induced hepatocellular carcinoma in mice. Although the incidence of this type of tumor was not considered significant, the similarity in lesions produced by other members of this chemical class raised a concern that the marginal results may well be biologically important. Nevertheless, neither the International Agency for Research on Cancer (IARC) nor the Carcinogen Assessment Group of the U.S. Environmental Protection Agency (EPA) has classified 1,1-dichloroethane as to carcinogenicity, placing it into Group D -- Not Classified chemical.

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**SUGGESTED OUTLINE FOR THE ROCKY FLATS PLANT OPERABLE UNIT NO 2
(903 PAD, MOUND, AND EAST TRENCHES AREAS)
ENVIRONMENTAL EVALUATION REPORT**

EXECUTIVE SUMMARY

LIST OF ACRONYMS

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- General problem at site
- Rocky Flats Plant and Operable Unit
- Scope of EE

1 2 SITE BACKGROUND

- Site environmental description
 - Topography and Geology
 - Hydrogeology and Hydrology
 - Ecology
 - Meteorology
- Site Map
- General History
 - Source Areas
 - Plant operations
 - Known or potential contaminants
 - Adjacent Operable Units
- Geographic location relative to off-site areas of interest
- General sampling locations and media

1 3 SCOPE OF ENVIRONMENTAL EVALUATION

- Assignment and rationale
- Overview of study design

1 4 ORGANIZATION OF ENVIRONMENTAL EVALUATION REPORT

2 0 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2 1 GENERAL CONSIDERATIONS PERTAINING TO THE ROCKY FLATS PLANT

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- Prior surveys and field investigations
- Other reports and data

2 2 OPERABLE UNIT NO 2

- Area- and media-specific collection strategy
- Data from site investigations
 - Summary of methods and quality control
 - Data analysis
- Uncertainties, limitations, gaps in quality of data

2 3 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

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- Receptors

3 0 EXPOSURE ASSESSMENT

3 1 CHARACTERIZATION OF EXPOSURE SETTING

- Physical setting
 - Climate
 - Vegetation
 - Soil types
 - Surface hydrology
 - Ground water hydrology
 - Ecological habitats (e g , prairie, pond, riparian vegetation)
- Potentially exposed populations
 - Nature and extent of contamination
 - Assessment of sensitive environments
 - Habitats potentially affected by site contamination
 - Populations potentially exposed to contaminants

3 2 IDENTIFICATION OF EXPOSURE PATHWAYS

- Sources and receiving media
- Fate and transport in release media
 - Physical, chemical, and biological processes
 - Decomposition rates and products
 - Bioaccumulation potential
- Exposure points and exposure routes

3 3 POTENTIAL FOR EXPOSURE

- Seasonal or climatic variations
- Site-specific geophysical, physical, or chemical conditions

3 4 QUANTIFICATION OF EXPOSURE

- Exposure point concentrations
- Route of intake

3 5 CONTAMINANT CONCENTRATION ASSESSMENT

- Exposure concentration versus criteria/standards in water, soil, and air
- Exposure concentration versus toxicity data from literature
- Identification of Uncertainties
- Summary of Exposure Assessment

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- Periphyton
 - Algal types, species diversity, standing crop (biomass), productivity
- Benthic Macroinvertebrates
 - Abundance, species diversity, tolerant/intolerant species, biomass, fecundity

4 2 TERRESTRIAL ENVIRONMENTS

- Grassland Flora
 - Herbaceous and shrub species, cover class, biomass, primary production, dominant species
- Grassland Fauna
 - Species diversity, standing crop, variety of vertebrates and invertebrates, evidence of stress
- Wetland Flora
 - Abundance, species diversity, biomass, production, visible evidence of stress

4 3 EVALUATION OF POTENTIALLY AFFECTED HABITATS

4 4 EVALUATION OF POTENTIALLY AFFECTED POPULATIONS

4 5 SUMMARY OF ECOLOGICAL EVALUATION

5 0 TOXICITY ASSESSMENT

5 1 PROFILE OF TOXIC EFFECTS FOR CONTAMINANTS OF CONCERN

5 2 EXPOSURE PERIODS AND INTAKE

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5 5 SUMMARY OF TOXICITY INFORMATION

6 0 RISK CHARACTERIZATION

6 1 SUMMARY OF RISKS

- Based on criteria/standards
- Based on toxicity assessment
- Based on bioaccumulation data
- Based on comparative ecology assessment

6 2 OVERALL SCENARIO OF RISK ASSESSMENT

7 0 SUMMARY

- 7 1 CHEMICALS OF POTENTIAL CONCERN**
- 7 2 EXPOSURE ASSESSMENT**
- 7 3 ECOLOGICAL EVALUATION**
- 7 4 TOXICITY ASSESSMENT**
- 7 5 RISK CHARACTERIZATION**
- 7 6 LIMITATIONS OF ANALYSIS**

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LIST OF ACRONYMS

AEC	U S Atomic Energy Commission
ARARs	Applicable or Relevant and Appropriate Requirements
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability At of 1980
CFR	Code of Federal Regulations
Ci	Curies
CLP	Contract Laboratory Program
cm	centimeter
CMS/FS	Corrective Measure Study/Feasibility Study
CWA	Clean Water Act
DOE	U S Department of Energy
EPA	U S Environmental Protection Agency
ERHSP	Environmental Restoration Health and Safety Project Plan
FS	Feasibility Study
g/l	grams per liter
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
HASL	Health and Safety Laboratory
IAG	Inter-Agency Agreement
IHSS	Individual Hazardous Substance Site
IRIS	Integrated Risk Information System
LDRs	Land Disposal Restrictions
MCLGs	Maximum Contaminant Level Goals
MCLs	Maximum Contaminant Levels
mCi/km ²	milliCuries per square kilometer
OU	Operable Unit
pCi/g	picoCuries per gram
pCi/l	picoCuries per liter
PPCD	Prevention of Contaminant Dispersion
PQLs	Practical Quantitation Limits
QAPJP	Quality Assurance Project Plan
RAAMP	Radioactive Ambient Air Monitoring Program
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act of 1976
RfDs	Risk Reference Doses
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SAP	Sampling and Analysis Plan

TABLE OF CONTENTS (Continued)

LIST OF ACRONYMS (Continued)

SAS	Special Analytical Services
SDWA	Safe Drinking Water Act
SOP	Standard Operating Procedure
SSHSP	Site-Specific Health and Safety Plan
SWMU	Solid Waste Management Unit
TSP	Total Suspended Particulate
VOC	Volatile Organic Carbon
$\mu\text{Ci}/\ell$	microCuries per liter
$\mu\text{Ci}/\text{m}^2$	microCuries per square meter
$\mu\text{g}/\text{kg}$	micrograms per kilogram

RESPONSES TO EPA AND CDH COMMENTS

5 1 RESPONSES TO EPA COMMENTS DATED 14 MAY 1990

EPA1-1 COMMENT

Executive Summary

The bedrock RI/FS workplan for Operable Unit Number 2 (OU 2) will be titled Phase II RFI/RI Workplan (bedrock), not Phase III

Plutonium and americium are also observed in seeps downgradient of the 903 Pad and in the upper reaches of South Walnut Creek This must be evaluated and discussed within the draft Phase II RFI/RI Report

RESPONSE

The bedrock Remedial Investigation/Feasibility Study (RI/FS) work plan for Operable Unit Number 2 (OU No 2) will be titled the Phase II RCRA Facility Investigation/Remedial Investigation (RFI/RI) Work Plan (Bedrock) and is referenced as such in the Revision I of the Final Phase II Work Plan (alluvial) (see p ii)

Reference to the presence of plutonium and americium in two seeps (SW-50 and SW-53) downgradient of the pad has been added in the Executive Summary Their presence may be attributed to the water from the seeps coming in contact with surface soils exhibiting elevated concentrations of these radionuclides This theory will be evaluated and discussed within the draft Phase II RFI/RI Report (see p ii)

EPA1-2 COMMENT

Section 1.0

The Bedrock Work Plan is also a Phase II Work Plan It is not a Phase III Work Plan

RESPONSE

See previous response

EPA1-3 COMMENT

Section 1.4.1.1

The location of the burial grounds for the drums containing plutonium contaminated sludge is important to determine as a part of this RFI/RI 4.54×10^3 gm/l plutonium does not correlate to 280 pico Ci/l plutonium

RESPONSE

Available historical references were reviewed in an attempt to determine the location of the burial grounds for the drums containing plutonium contaminated sludge. The information is not provided. The location will be further investigated during the RFI/RI.

4.54×10^{-3} grams per liter (g/l) of plutonium correlates to 280 microCuries per liter ($\mu\text{Ci/l}$), not 280 picoCuries per liter (pCi/l). The error has been corrected in the text (see p 1-25).

EPA1-4 COMMENT

Section 1.4.1.2

The off-site disposal location of the plutonium contaminated soils removed from the 903 Lip Site must be determined as part of this RFI/RI.

RESPONSE

This information is not provided in the available references. The disposal location will be further researched during the RFI/RI.

EPA1-5 COMMENT

Section 1.4.1.4

It is important to know what is meant by destruction of lithium, calcium, magnesium and solvents at site 140 so that the RFI/RI can incorporate this information in characterizing the site. Implementation of the workplan must address this issue.

RESPONSE

The references do not provide any information more descriptive concerning the method of destruction of lithium, calcium, magnesium, and solvents at site 140. It is presumed, however, that the method of destruction for metals was burning (oxidation) of the elemental form. It is possible that additional information will be discovered during preparation of the Historical Release Report.

EPA1-6 COMMENT

Section 1.4.2.1

It is important to ascertain the condition of the drums when the drums were removed from the Mound Site. The RFI/RI must determine if the surficial radionuclide contamination of soil is the result of wind dispersion of contaminants from the 903 Pad Site.

RESPONSE

The condition of the drums when removed from the Mound Site is not provided in the available references. An attempt will be made to acquire this information for the draft Phase II RFI/RI Report.

The hypothesis that surficial radionuclide soil contamination is the result of wind dispersion of contaminants from the 903 Drum Storage Site will be evaluated during the RFI/RI.

EPA1-7 COMMENT

Section 1 4 2 2

It is important to determine the off-site disposal location of the two drums unearthed in 1968 from this site. This information must be presented within the draft Phase II RFI/RI for OU 2.

RESPONSE

The off-site disposal location of the two drums unearthed in 1968 from Individual Hazardous Substance Site (IHSS) No. 108 cannot be determined from the currently available references. Additional research will be conducted in an attempt to gather this information for the RFI/RI.

EPA1-8 COMMENT

Section 2 2 2 2

Implementation of the final workplan must reflect information gathered as a result of the seismic study ongoing.

RESPONSE

Section 2 2 1 2 (formerly Section 2 2 2 2) has been modified to discuss the current understanding of bedrock geology based on the results of the seismic reflection study, a comprehensive literature search, reprocessing and describing previously collected core samples, and collecting and analyzing selected samples for grain size analyses (see pp. 2-5 through 2-10).

EPA1-9 COMMENT

Section 2 3 1

Table 2-4 within this section should have been revised to reflect the actual number of samples utilized to calculate tolerance intervals. This information must be updated in the draft Phase II RFI/RI Report for OU 2.

RESPONSE

Table 2-3 (previously Table 2-4) does reflect the actual number of samples used to calculate tolerance intervals for each geologic material (see p. 2-19).

EPA1-10 COMMENT

Section 2.3.2.1

The draft Phase II RFI/RI Report must be based on use of appropriate analytical procedures. Procedures should have been identified within the workplan which would allow information derived from the Phase I investigation to be verified or refuted. The Phase I investigation seems to have relied upon medium level CLP procedures utilizing inappropriate detection limits for volatile organic

compounds. The final workplan should have referenced the data validation of the Phase I data. The draft Phase II RFI/RI Report must reference this information and the RFI/RI work must incorporate and utilize appropriate analytical procedures.

The final Phase II RFI/RI Workplan for OU 2 should have identified that acetone, 2-butanone, chloroform, 4-methyl-2-pentanone, toluene, ethyl benzene, and xylenes appear to be present at Trench T-2. The final workplan should not have excluded the possibility of the presence of methylene chloride, trans-1, 2-dichloroethene, chloroform, trichloroethene, phthalates, and cis-1, 3-dichloropropene from the 903 Pad Area. This information cannot be excluded from the draft Phase II RFI/RI Report.

RESPONSE

The analytical procedures to be used during Phase II are identified in the Quality Assurance Addendum (QAA) presented in Section 9.0 of the Phase II Work Plan. Organic and metal analyses will be performed using Contract Laboratory Program (CLP) routine analytical services, and radionuclide and inorganic analyses will be performed in accordance with the methods specified in the General Radiochemistry and Routine Analytical Services Protocol (GRRASP). Analytical methods with detection limits below or near chemical-specific ARARs will be used to facilitate comparison of resulting data to Applicable or Relevant and Appropriate Requirements (ARARs).

Validation codes will be presented in the draft Phase II RFI/RI Report.

The presence of acetone [micrograms per kilogram ($1100 \mu\text{g/kg}$)], ethyl benzene ($780 \mu\text{g/kg}$), and total xylenes ($3300 \mu\text{g/kg}$) in the soils just south of Trench T-2 is acknowledged in the text. Toluene ($640 \mu\text{g/kg}$) was added to the list of volatile organics detected at Trench T-2 as was a reference to the presence of chloroform and 2-butanone at concentrations estimated below the detection limit. Toluene, chloroform, and 2-butanone were originally not identified as possible contaminants at Trench T-2 since toluene was detected in only one sample and both chloroform and 2-butanone were estimated at concentrations below the detection limit. The lack of acknowledgement of these compounds in Phase I boreholes at Trench T-2 does not change the proposed work plan. 4-methyl-2-pentanone was not detected in any soil samples from boreholes BH25-87, BH26-87, BH27-87, or BH28-87 (see p. 2-37).

The work plan does not exclude the possibility of the presence of volatile organics at the 903 Pad Area. It does indeed state that, based on soil boring analytical results from Phase I, volatile organics are present in the soil and adjacent to the pad. Additional boreholes drilled during Phase II will verify this conclusion. All soils data will be presented in the draft Phase II RFI/RI Report.

EPA1-11 COMMENT

Section 2.3.2.2

The Oil Burn Pit No. 2 is SWMU No. 153, not SWMU No. 158.

The final Phase II RFI/RI Workplan for OU 2 should have clarified which existing and proposed boreholes will be used to characterize each SWMU, and the numbers and types of soil samples to be collected at each borehole. This information must be included within the draft Phase II RFI/RI Report for OU 2.

Conclusions regarding the presence of plutonium and americium as a result of the wind dispersion of material from the 903 Pad are not acceptable and cannot be substantiated with the present information. The draft RFI/RI Report must substantiate or refute this theory.

RESPONSE

The Oil Burn Pit No 2 is IHSS No 153, not IHSS No 158 The correction has been made in the text (see p 2-37)

The boreholes from the Phase I investigation used to characterize each IHSS are presented in Sections 2 3 2 1 (903 Pad Area), 2 3 2 2 (Mound Area), and 2 3 2 3 (East Trenches Area) The proposed boreholes for the Phase II field investigation are discussed in Section 5 3 along with an explanation of the sampling methodology

The hypothesis that surficial radionuclide soil contamination is the result of wind dispersion of contaminants from the 903 Pad will be evaluated during the RFI/RI

EPA1-12 COMMENT

Section 2 3 2 3

The draft Phase II RFI/RI Report must be based on use of appropriate analytical procedures Procedures should have been identified within the workplan which would allow information derived from the Phase I investigation to be verified or refuted The Phase I investigation seems to have relied upon medium level CLP procedures utilizing inappropriate detection limits for volatile organic compounds The final workplan should have referenced the data validation of the Phase I data The draft Phase II RFI/RI Report must reference this information and the RFI/RI work must incorporate and utilize appropriate analytical procedures

In order to verify that the plutonium and americium contamination of the soil is limited to the surface, the subsurface soils must also be sampled and analyzed for radionuclides (see comment on Section 5 2 3 below)

The final workplan should have indicated that phthalates and 2-butanone were above detection limit within samples from boreholes at trenches T-3, T-4, T-10 and T-11 The final workplan should have indicated that 1,1, 1-trichloroethane, toluene, and xylenes appear to be present within boreholes drilled within trenches T-5 through T-9 The draft Phase II RFI/RI Report must reflect this

RESPONSE

The analytical procedures to be used during Phase II are identified in Section 9 0 of the Phase II Work Plan Organic and metal analyses will be performed using CLP routine analytical services, and radionuclide and inorganic analyses will be performed in accordance with the GRRASP-specified methods Analytical methods with detection limits below or near chemical-specific ARARs will be used to facilitate comparison of resulting data to ARARs

Validation codes will be presented in the draft Phase II RFI/RI Report

The parameter list for the source characterization boreholes is presented in Table 5-3 The radionuclide analytes include gross alpha, gross beta, uranium-233 + 234, 235, and 238, americium-241, plutonium-239 + 240, tritium, strontium-90, 89, and cesium-137 A discussion of the sampling protocol is provided in Section 5 2

The work plan has been revised to acknowledge the presence of di-n-butyl phthalate at concentrations estimated below the detection limits in four samples from boreholes at trenches T-3, T-4, T-10, and

T-11 The presence of bis (2-ethylhexyl) phthalate at a maximum concentration of 880 µg/kg in BH45-87 (0-9.5' interval) was also added to this discussion. In addition, the detection of 2-butanone in samples from this area is also acknowledged in the modified text. The detection of toluene, 1,1,1-TCA, and xylenes at concentrations estimated below the detection limit in samples from Trenches T-5 through T-9 has been added to the text. The majority of these compounds were estimated at concentrations below the detection limits and therefore were not identified as potential contaminants in the original plan. The acknowledgement of these compounds in the final workplan does not change the proposed activities (see p. 2-39).

EPA1-13 COMMENT

Section 2.3.3

This section should have clarified how first quarter 1989 site specific well data is compared to second quarter background information. Also, this section should have explained why maximum detected values were utilized instead of upper tolerance limit values, when available. The draft Phase II RFI/RI Report for OU 2 must provide this explanation.

This section should have discussed the designations of the flagged analytical results as they pertain to results estimated above/below detection limits so as to clarify the interpretation of results. The draft Phase II RFI/RI Report must include this explanation. Table 2-9 must be updated in the draft RFI/RI Report to reflect excluded ground water data referenced within EPA comments on the draft Phase II RFI/RI Workplan, Section 2.3.3.1.

RESPONSE

The text has been modified to clarify that all data (with the exception of radionuclide data) discussed in Section 2.3.3 were collected during the second quarter of 1989. However, site-specific radionuclide data relies on first quarter results because complete second quarter site-specific data are unavailable (see p. 2-4).

Errors were found in Table 2-12A through C (previously Table 2-10) and Tables 2-13A through F, 2-14A through F, and 2-15A through F (previously Table 2-11) listing some background values as maximum detected values when they are indeed the upper limit of the tolerance intervals and vice versa. The errors have been corrected and therefore data are only compared to maximum detected values when tolerance intervals are unavailable (see p. 2-41).

A brief discussion has been added to Section 2.3.3 on data value qualifiers "J" and "E" as reflecting concentrations estimated below and above the detection limit, respectively. This explanation is also presented on the data printouts in the appendices (see p. 2-41).

The "J" qualifier signifies that the analytical result for a parameter was outside the standard curve range for both the undiluted (high end) and diluted (low end) sample, and therefore, the result is considered approximate. It is important to retain this record of limited accuracy, while still reporting that some contamination may be present.

Table 2-11 (previously Table 2-9) was revised and corrected in Revision 1 of the Final Phase II RFI/RI Work Plan (alluvial) for OU No. 2, as appropriate.

EPA1-14 COMMENT

Section 2 3 3 2

Why are second quarter 1989 well analytical results compared to maximum detected values instead of calculated tolerance intervals for ground water radionuclide data in Table 2-10? Table 2-11 should have been clarified to note that the background figures presented for comparison to all previously collected data may not represent background for quarters other than the second quarter of 1989. Thus, this serves as a qualitative comparison only. The data presented within Table 2-11 for radionuclides in ground water should be compared to the 1989 second quarter tolerance interval, not the maximum detected level for the second quarter of 1989, even though this tolerance interval is not directly applicable to all data previously collected and is only a qualitative indicator for data collected previous to the second quarter 1989. These explanations must be presented within the draft RFI/RI Report for OU 2.

The work implemented to support the draft Phase II RFI/RI for OU 2 must substantiate or refute the evaporative concentration theory and substantiate or refute the transport of contaminants by the south interceptor ditch.

RESPONSE

Tables 2-12A through C (previously Table 2-10) and Tables 2-13A through F, 2-14A through F, and 2-15A through F (previously Table 2-11) have been corrected to reflect upper limits of the tolerance intervals where available. Maximum detected concentrations are only used for comparison where tolerance intervals are unavailable (see p 2-41).

A statement has been added to Section 2 3 3 2 to explain that the background figures presented for comparison in Tables 2-12A through C (previously Table 2-10) and Tables 2-13A through F, 2-14A through F, and 2-15A through F (previously Table 2-11) are for qualitative comparison, and may not represent background for other quarters in 1989 (see p 2-51).

The conceptual model that local concentrations of certain contaminants are due to evaporation of shallow ground water will be further investigated during the Phase II activities, and the results will be presented in the draft Phase II RFI/RI report. This investigation will determine the role of the South Interceptor Ditch in contributing to the elevated major ion concentrations in well 29-87.

EPA1-15 COMMENT

Section 2 3 5 2

Data and sampling locations for samples taken in October, 1989 must be presented within the draft Phase II RFI/RI Report for OU 2.

RESPONSE

The analytical results for the samples collected in October 1989 will be presented in the draft Phase II RFI/RI Report.

EPA1-16 COMMENT

Section 2.4

This section should have been titled Chemical Specific Applicable or Relevant and Appropriate Requirements. The following comments on the ARAR analysis are intended, in part, to conform the ARAR analysis to specific requirements of the revised NCP and will require the reformulation of Table 2-12, potential chemical specific ARAR concentrations when presented within the draft Phase II RFI/RI Report for OU 2

- The ARAR screening process should not be performed serially. Rather, relevant and appropriate requirements are considered in the same manner as applicable requirements. When more than one ARAR is identified, the most stringent ARAR is to be used.*
- Pursuant to the NCP [40 CFR 300.430 (e)(2)(i)(B)], MCLGs must be attained for remedial actions for ground or surface waters that are current or potential sources of drinking water. Where the MCLG is set at level of zero, the MCL must be attained.*
- Pursuant to the NCP (40 CFR 300.430 (e)(2)(i)(E)), Water Quality Criteria must be attained where relevant and appropriate.*
- Pursuant to the NCP (40 CFR 300.430 (e)(2)(i)(A)(2)), the 10E-6 risk level is to be used for carcinogens which do not have an ARAR. In particular, this should be evaluated for strontium. In addition, in evaluating the potential alternatives, all ARARs taken together should not present a cumulative risk in excess of 10E-4. If such risk would be exceeded for a particular alternative, the ARARs may need to be scaled back accordingly (see also 40 CFR 300.430 (e)(2)(i)(D)).*
- RCRA LDR is an action specific ARAR, triggered by the placement of a restricted waste. For the purposes of identifying chemical specific ARARs prior to screening remedies, the RCRA LDR standards in Subpart D or 40 CFR part 268 should be classified as "items to be considered".*

The newly promulgated applicable CDH surface water standard for trihalomethanes is 190 ppb. The newly promulgated applicable CDH surface water standard for 1, 1, 2, 2-tetrachloroethane is 170 parts per trillion. Although contaminant concentrations in ground water were estimated below detection limits, ARARs analyses must be presented for methylene chloride, acetone, carbon disulfide, 1, 2-dichloroethene and toluene. Potential ARARs for phthalates and PCBs must also be presented. This information must be revised within the draft RFI/RI Report for OU 2.

RESPONSE

The discussion of ARARs has been substantially revised and broken out as a separate section, Section 7.0. Proposed chemical-specific ARARs for OU No. 2 ground water are now summarized as Table 7-1.

Potential ARARs considered for ground water and soils/sediments are discussed in Section 7.4 and 7.6, respectively, and determined either to be ARAR or not. The most stringent standard available was selected for each constituent and presented in Table 7-1.

ARARs discussions have been revised to incorporate the following NCP [FR Vol 55, No. 46, 8848, 40 CFR 300.430 (e)] considerations in development of remediation goals:

1. Proposed ARARs,

- 2 for systematic contaminants, concentration levels that will not cause adverse effects to the human population and sensitive subgroups over a lifetime of exposure,
- 3 for carcinogens, concentration levels that represent an excess lifetime individual cancer risk less than 10^{-4} considering multiple contaminants and multiple pathways of exposure,
- 4 factors related to detection limits,
- 5 attainment of Maximum Contaminant Level Goals (MCLGs) [or Maximum Contaminant Levels (MCLs if MCLGs are zero)] if water is a current or potential source of drinking water, and,
- 6 attainment of Clean Water Act (CWA) water quality criteria where relevant and appropriate

Identification of action-specific ARARs, including RCRA Land Disposal Restrictions (LDRs), and remediation goals is a part of the Feasibility Study (FS) process and will be addressed in the Corrective Measure Study/Feasibility Study (CMS/FS) Report. Modification and/or establishment of remediation goals based on risk consideration will also be a part of the CMS/FS Report. The Colorado Department of Health (CDH) surface water trihalomethane standard is 190 ppb, and ARARs [(or To Be Considereds (TBCs))] are shown for all volatiles detected in ground water (1,1,2,2-tetrachloroethane was not detected and has been removed from the table). Phthalates and PCBs have only been detected in soils. Chemical-specific ARARs for organic contaminants in soils do not exist and must be determined through a risk assessment.

EP1-17 COMMENT

Section 3.1

Concerning the Table 3-1 objective of characterizing the nature and extent of contamination, DOE must also include evaluation of the horizontal and vertical extent of inorganic and organic contamination in soils external to SWMUs. This addition must be carried forward through Sections 4.0 and 5.0 of the workplan and must be implemented and the resulting information presented within the draft Phase II RFI/RI Report for OU 2. The characterization of sources must be completed regardless of the past removal of wastes from some of the sites. This information must be provided within the draft Phase II RFI/RI Report for OU 2.

RESPONSE

Contamination beyond IHSS boundaries would have occurred through migration primarily by ground-water transport and wind dispersion (e.g., plutonium). Accordingly, contamination beyond the IHSS boundaries is being investigated by use of monitoring wells for determination of ground-water quality and soil profiles for plutonium contamination.

EPA1-18 COMMENT

Section 3.2

Table 3-2 must be modified to reflect the new NCP modification of the ARARs analysis presented in Section 2.4 and the update of the CDH standards for trihalomethanes and 1, 1, 2, 2-tetrachloroethane as indicated in comments pertaining to Section 2.4 above.

The final workplan should have identified workplan items designed to provide information not present in the Phase I RI. These shortcomings must be identified, corrected and presented within the draft Phase II RFI/RI Report for OU 2

RESPONSE

Table 3-2 has been removed because it provided redundant information relative to Table 7-1 (formerly Table 2-13)

Section 3.1 summarizes the conclusions of the previous investigations conducted at OU 2. Along with the general conclusions, this section identifies issues that were not resolved during these investigations. For example, further characterization of potential contaminant sources is needed, the nature and extent of contamination has not been fully determined, and additional characterization of the unconfined ground-water flow system is necessary.

Table 3-1 cites the objectives of the Phase II RFI/RI work plan. These objectives and the associated proposed planned activities target the shortcomings identified in Section 3.1.

EPA1-19 COMMENT

Section 4.1.3

The brief description of the activities required for the remedial investigation do not correlate to the objectives presented within Section 3.2 of the workplan. For example, not just the surface soils will be sampled and analyzed for radionuclide contamination.

RESPONSE

Revisions have been made to Section 4.1.3 of the workplan to ensure that the activities required for the remedial investigation correlate to the objectives of the Phase II RFI/RI (see p. 4-2).

EPA1-20 COMMENT

Section 4.1.6

For clarity, this section should have further stated that the risk assessment will assume no institutional controls. The risk assessment to be presented within the draft Phase II RFI/RI Report for OU 2 must reflect this requirement.

RESPONSE

The text has been modified to state that the risk assessment will assume no institutional controls (see p. 4-5).

EPA1-21 COMMENT

Section 4.1.6.2

EPA1-21 COMMENT

Section 4.1.6.2

This section describes work which may be required to evaluate environmental impact associated with the disposal practices at OU 2. Data needs and actual workplan objectives are not described or defined within Section 3.0 of the workplan. The draft RFI/RI must present this information and a detailed description of the methods utilized to realize these data needs.

RESPONSE

Table 3-1 in Section 3.2 has been revised to provide objectives and data needs for assessing environmental impacts related to disposal practices at OU No. 2. The Environmental Evaluation Workplan for OU No. 2 is now presented in Section 6.0 of this Work Plan.

EPA1-22 COMMENT

Section 4.2.2.1

The compliance with ARARs section should have been reworded to state "The analysis will address compliance with chemical specific, location specific and action specific ARARs in accordance with the NCP. If an alternative will not comply with an ARAR, the FS report will propose a basis for justifying a waiver, if appropriate." The draft Phase II RFI/RI Report must be prepared to reflect this change.

RESPONSE

The text has been modified as directed in this comment (see p. 4-20).

EPA1-23 COMMENT

Section 4.2.3

The progression of Feasibility Study documents is draft to final. Under the proposed IAG, there is no provision for the Feasibility Study to go to public comment. The Proposed Plan goes to public comment.

RESPONSE

The discussion in Section 4.2.3 describing the progression of the Feasibility Study Report has been modified to explain that the final FS will incorporate EPA and CDH comments. No reference to public comments are made (see p. 4-22).

EPA1-24 COMMENT

Section 5.0

DOE must present rationale for not analyzing both filtered and unfiltered samples for metal constituents.

In general, wells at OU No 2 do not yield sufficient quantities of water to perform both filtered and unfiltered analysis. Dissolved metals analysis provides the best representation of the metals within ground water capable of migrating in this medium. Total metals analysis would reflect dissolved metals and those leached from sediments within the well and is less amenable to interpretation.

EPA1-25 COMMENT

Section 5.1.1

It is unclear how Table 5-1 correlates with statements made in this section concerning well screened interval. The well screened interval tables should have followed the procedures outlined within this section.

An alluvial monitoring well must be located approximately 150 feet south southeast of newly proposed well 85-90. New well 35-90 must be relocated approximately 50 feet west of proposed location.

RESPONSE

Table 5-1 presents the anticipated screened interval for each proposed monitoring well based on historical water level information. The table and associated text now state that if the saturated thickness at a location is greater than ten feet, multiple wells will be installed. It is not prudent at this time to base well numbers on estimated saturated thicknesses.

An alluvial well (105-91) has been added approximately 150 feet south southeast of the proposed well 85-91 to investigate ground-water quality downgradient of the 903 Pad Area. Well 35-91 has been relocated approximately 50 feet west of the original proposed location to provide a better location for defining the plume north of Trench T-3.

EPA1-26 COMMENT

Section 5.1.1.3

DOE must not reduce the parameter list for analysis of ground water samples prior to receiving approval from the regulatory agencies.

RESPONSE

DOE will consult with EPA and CDH prior to reducing the analyte list (see p. 5-35).

EPA1-27 COMMENT

Section 5.2.1.2

Boreholes must be located immediately downgradient of sites 153 and 154. These boreholes must be located as close to the source sites as is allowed. Boreholes must be located on both sides of site 108 in addition to the proposed monitoring wells. The draft RFI/RI Report for OU 2 must include this requirement. A borehole must be placed to characterize the potential for a source to be located within site 183.

RESPONSE

As discussed in Section 5.2.1.2, the western area of the Pallet Burn Site is inaccessible and therefore additional borings are not proposed. An additional borehole (BH2891) will be drilled in the eastern area to aid in verifying the IHSS location (see p. 5-19).

Additional boreholes suggested by EPA for site 108 will not be drilled due to the presence of the barrels throughout the site. As explained in response to EPA comment on Section 3.1, contamination beyond IHSS boundaries will be investigated through the use of monitoring wells and soil profile samples. Boreholes will only be drilled for source characterization.

A monitor well and borehole (106-91/BH4691) have been added to characterize the potential source within the gas detoxification site and to investigate ground-water quality beneath the site.

EPA1-28 COMMENT

Section 5.2.1.3

Boreholes must be placed external to, and downgradient from sites within the East Trenches Areas. This is necessary in order to verify the results of the Phase I investigation. These boreholes must be sampled for all constituents listed within Table 5-5. If Trench T-10 is filled with barrels, boreholes must be drilled adjacent to this site and Figure 1-5 should have been modified to reflect this information. Boreholes and wells must be completed and sampled in surface water drainages downgradient of the east spray fields to evaluate the effect they have had on these drainages. The draft phase II RFI/RI Report must include information derived from inclusion of these boreholes.

RESPONSE

Boreholes are drilled to investigate potential source areas. Boreholes will not be drilled outside of IHSS boundaries since contaminant migration via ground water will be investigated by installing and sampling monitor wells. As described in Section 5.2.1.3 alluvial monitor wells 38-91 and 39-91 will be installed between Trenches T-3/T-4 and T-11/T-10 in an attempt to differentiate the two groups of trenches as contaminant sources. Wells 40-91 and 41-91 will be located southeast of Trench T-10 to further characterize the extent of volatile organics in alluvial ground water.

EPA1-29 COMMENT

Section 5.2.3

Given that stored and buried drums contained plutonium and uranium, the soils must be sampled for plutonium 239 and 240, americium 241 and uranium 233/234, 235 and 238. Also, if the one meter depth proposed for the vertical profile indicates that radionuclides are found at depth, further characterization may be warranted. It would be prudent to sample small discrete intervals within proposed boreholes drilled into and adjacent to sites known to have contained radionuclides to verify the premise that 903 Pad is responsible for the radionuclides present in the soils affected by OU 2. This is necessary as some borehole samples taken at depth do indicate the presence of plutonium and americium.

RESPONSE

Table 5-3 (previously Table 5-5) lists the source sampling parameters for the borehole soils. The radionuclides include gross alpha, gross beta, uranium-233+234, 235, and 238, americium-241, plutonium-239, 240, tritium, strontium-90, 89, and cesium-137. Boreholes to be drilled into IHSSs will extend from the ground surface to the base of weathered bedrock. Continuous samples will be collected for geologic descriptions for the entire borehole depth. From this core, discrete samples will be submitted for laboratory chemical analysis at the water table. In addition, a discrete sample will be collected for chemical analysis at the water table. Core from saturated surficial materials will not be submitted to the laboratory, as the presence of water in this zone will affect interpretation of chemical results. In order to prevent alluvial ground water from affecting weathered bedrock samples, surface casing will be grouted into the borehole through surficial materials. Subsequent to grout hardening, the borehole will then be advanced through weathered bedrock with continuous sampling. Discrete samples from the core will be submitted to the laboratory for chemical analysis from two feet immediately below the casing, and every four feet thereafter to the base of weathering. With regard to the plutonium/americium profiles at the surface, a one meter depth sample is almost assuredly not going to show elevated plutonium/americium unless the sampling location is at, or adjacent to, an IHSS where these radionuclides were disposed and have been released to the environment. In this case, the boreholes will provide the needed data for greater depths.

5 2 RESPONSES TO EPA COMMENTS DATED 15 MARCH 1990

[These EPA comments correspond to the draft work plan submitted in December 1989. They were received by DOE in late March 1990, which did not provide sufficient time for incorporation into the Final Work Plan (12 April 1990). Accordingly, responses to these comments are provided below, and Revision 1 of the Final Work Plan includes modifications that address these comments.]

GENERAL COMMENTS

EPA2-1 COMMENT

In general, the draft workplan for the baseline risk assessment conforms to EPA guidance for risk assessments. However, you should be aware that the region is now in the process of developing a "generic" workplan for risk assessments. Once completed, EPA will forward this information to you. This workplan will, in general, conform to plans now in existence and those under development in other regional offices. Included in the workplan will be a set of regionally specific exposure parameters to be used in the exposure assessment portion of the baseline risk assessment. Deviation from these exposure parameters will require adequate documentation, and the approval of EPA.

RESPONSE

Region-specific exposure parameters determined by EPA will be used where available. Any proposed deviation from the parameters will be documented and submitted to the EPA for approval prior to preparation of the risk assessment (see p 4-10).

SPECIFIC COMMENTS

EPA2-2 COMMENT

Page 4-6. Paragraph 3. Objectives

Objective 2 includes fate and transport analysis within environmental media. It is also essential that the baseline risk assessment address cross media fate and transport. For instance, such analysis must include contamination of ground water from soil sources, contamination of air from soils or water, etc.

RESPONSE

Cross-media fate and transport will be considered.

EPA2-3 COMMENT

Page 4-7. Paragraph 1. Documents to be used

In addition to the documents listed in Table 4-1, EPA will be using documents included on the attached list for development and review of the baseline risk assessment.

RESPONSE

Table 4-1 of the work plan has been revised to include the documents EPA listed for use in risk assessment preparation and evaluation

EPA2-4 COMMENT

Page 4-9 Paragraph 1 Contaminants to be considered

The following criteria must be used in identifying chemicals to be addressed in the baseline risk assessment

- a) *Those chemicals positively detected in at least one CLP sample [Routine Analytical Services (RAS) or Special Analytical Services (SAS)] in a given medium, including chemicals with qualifiers attached indicating known identities, but unknown concentrations*
- b) *Chemicals detected at levels elevated above background*
- c) *Chemicals which have been tentatively identified and may be associated with the site based on historical information, or have been confirmed by SAS*
- d) *Transformation products of site associated chemicals*

It is unclear what is meant in the draft workplan by "risk based detection limits" Analytical detection limits based upon the best available technology must be used

Chemicals must not be eliminated based upon environmental fate predictions until the exposure assessment phase of the baseline risk assessment is completed

RESPONSE

Criteria a, b, and c as listed in the comment above will be used in selecting site contaminants. It is not clear what level of detail is expected in the evaluation of potential transformation products. The prediction of the transformation products is dependent on the availability of transformation information in the scientific literature and on information regarding chemical, physical, and microbial site conditions. Quantitative estimates of transformation products would also be complicated, and depend on site-specific conditions as well as information regarding the approach to evaluating transformation products (see p 4-6)

Analytical detection limits are based upon the best available technology (see Section 9.0)

Chemicals will not be eliminated based on fate predictions until the exposure assessment is completed (see p 4-9)

EPA2-5 COMMENT

Page 4-10 Bullet 2. Exposure scenarios

Scenario selection should proceed regardless of the ability to quantify exposure. This may require exposure to be addressed qualitatively under circumstances where quantitative evaluation is not possible

RESPONSE

All plausible exposure scenarios will be identified, regardless of the ability to quantify exposure

EPA2-6 COMMENT

Page 4-10 Paragraph 2. Factors examined in pathway identification

In addition to the factors listed, detailed local meteorological data must be considered

It may be advantageous to consider receptor characteristics rather than "exposure scenarios" for the purpose of the baseline risk assessment. Each of the scenarios listed include several of the same receptor subpopulations. To avoid a duplication of effort, it may be more efficient to directly assess exposure and potential toxicity to subpopulations

RESPONSE

Detailed local meteorological data will be considered (see p 4-10)

To avoid duplication, the scenarios will be based on discrete subpopulations (e.g., residents and workers) (see p 4-9)

EPA2-7 COMMENT

Page 4-11 Paragraph 1. Cancer risk

It is not clear what is meant by the statement "Doses or the dose might result in an excess cancer risk for noncarcinogenic health". Please explain

RESPONSE

The statement "doses or the dose might result in an excess cancer risk for noncarcinogenic health" has been rewritten to state, "doses might exceed risk reference doses (RfDs) and or might result in an excess cancer risk greater than the acceptable target risk as defined by EPA (i.e., to 10^{-6} to 10^{-4})" (see p 4-10)

EPA2-8 COMMENT

Page 4-11 Paragraph 2 Critical toxicity values

Reference values for systemic or carcinogenic risk derived from SPHEM or PHRED will not be acceptable for use in the baseline risk assessments Both of the above sources are now obsolete and have been replaced

RESPONSE

Toxicity reference values from EPA's Integrated Risk Information System (IRIS) will be used in preference to other EPA reference values (see p 4-11)

EPA2-9 COMMENT

Page 4-12 Paragraph 2. Types of toxicity values

It will be unnecessary to generate toxicity values for subchronic exposure Chronic exposure will provide a more conservative assessment and will drive the rationale for any cleanup activity which may be indicated

The preferred terminology for acceptable intake for chronic exposure (AIC) is now "risk reference dose" (RfD) To avoid confusion, this terminology should be used throughout the baseline risk assessment and the AIC terminology should be discontinued

RESPONSE

Toxicity values will be generated for chronic exposure only

The term (risk) reference dose (RfD) will be used in the risk assessment to describe the toxicity value for acceptable chronic daily intake

EPA2-10 COMMENT

Page 4-12 Paragraph 3 Risk characterization

The reasonable maximum estimate of exposure (RME), based upon the 95% upper confidence limit of the exposure data, must be used throughout the baseline risk assessment process Details must be provided regarding the rationale and methodology for development of subchronic exposure estimates

RESPONSE

In accordance with EPA guidance, the upper 95 percent confidence limit of the exposure data will be used to calculate the exposure concentrations Based on the previous comment that there is no need to generate toxicity values, it is assumed that there will also be no need to develop subchronic exposure estimates

EPA2-11 COMMENT

Page 4-12 Paragraph 2. Aquatic toxicity

Where applicable, assessment of sediment toxicity must be included in the environmental portion of the risk assessment

RESPONSE

The text does not rule out an assessment of sediment toxicity, and such an assessment will be included in the environmental evaluation where applicable

CDH-1 COMMENT

General Comments

This and other similar documents submitted for review by DOE do an excellent job of covering geology, demographics, physical location, ecology, and both underground and surface water, but they all lack good coverage of meteorological and fugitive emissions information. In this document wind dispersion is referred to once in Section 1.4.2.1 Mound Site (SWMU Ref No 113) but with little explanation. Particulates are a major method of transport for contaminants through reentrainment. Any leakage or spills of solids such as those from deteriorating pondcrete and construction activities of other soil disturbances will also add to fugitive particulates in the air which are a pollutant by themselves and may also carry other contaminants.

A second area of fugitive emissions which did not receive adequate consideration are fugitive VOC emissions. These may occur from drum leakage, spills, seeps, etc. While these emissions may be of minor levels they add to the total plant emissions and are never controlled. Both the VOC and particulate emissions can have impacts on both human health and the environment.

RESPONSE

Extensive meteorologic and air monitoring data exist for the Rocky Flats Plant. These data are reported in monthly and annual monitoring reports produced by Rockwell International and now EG&G. In addition, total long lived alpha and Volatile Organic Carbon (VOC) fugitive emissions were monitored during the Phase I RI. A discussion of this monitoring program was added to Section 2.3.6 of the work plan (pp 2-81 through 2-86). Monitoring of radioactive and VOC fugitive emissions will also be needed at OU No 2 during Phase II RFI/RI field activities. The Health and Safety Plan currently being prepared for OU No 2 will include plans for this monitoring.

CDH-2 COMMENT

Section 1.0

Figure 1-5

The location of the 903 Area "Lip" is inconsistent with the historical definition of the "Lip", particularly with regard to what was removed and the material shipped to NTS as low level radiological waste. The historical "Lip" is SE of the 903 Pad, over the brow of the hill (a depositional area of windblown contamination). The narrative does mention the removal in relation to the metals destruction area that occurred there also. Considerable covering and recontouring of the 903 Area has occurred which will complicate cleanup/removal.

RESPONSE

The 903 Pad "Lip" Area illustrated in Figure 1-5 is consistent with the area portrayed on the original Solid Waste Management Unit (SWMU) map found in the Comprehensive Environmental Assessment and Response Program Phase I document.

CDH-3 COMMENT

Section 1 3 1 2

Previous investigations, item 8 makes minor reference to meteorological studies but does not detail This should have included a study of fugitive particulates

RESPONSE

The annual environmental monitoring reports produced by Rockwell International and now EG&G cover ambient air quality monitoring for radioactive particulates (See Section 2 3 6, pp 2-81 through 2-86) There are several meteorological studies which will be reviewed during the Phase II RFI/RI if additional meteorological information is required Some deal with contaminant transport and resuspension of particulates (Langer, G "Fugitive Dust Measurements and Modeling", Langer G , 1989, "Resuspension of Rocky Flats Soil Particles Containing Plutonium")

The routine monitoring that has been done for Total Suspended Particulate (TSP) is included in both the monthly and annual Environmental Reports for Rocky Flats Data are available for TSP since 1981 at one location near the east entrance to the Plant

CDH-4 COMMENT

Section 1 4 1 1 Page 1-19

There is no reference to HASL-235 information which indicated that the loss of control of materials was greater than 86 grams It may be that other documents referenced do include discussion of HASL-235 et seq documentation Also recognize that statements made about inventory lost from control are time related, in that the plant boundary has changed over the years

RESPONSE

The investigative results presented in U S Atomic Energy Commission (AEC) Health and Safety Laboratory (HASL) Report HASL-235 reveal that an estimated 4 5 Curies (Ci) of Rocky Flats plutonium-239 are found in the soil bounded by the 3 milliCuries per square kilometer (mCi/km²) concentration contour around Rocky Flats as mapped in the document An additional 3 2 Ci could have been released from the Plant to remote areas beyond the 3 mCi/km² contour This release by wind dispersal would equal a total of 125 grams of plutonium-239 A reference to these findings has been added to Section 1 4 1 1 (see pp 1-21 through 1-23)

CDH-5 COMMENT

Section 1 4 1 2 Page 1-23

The off-site disposal location of the first two soil cleanups is unknown Is the off-site disposal location of the 214 tri-wall pallets of contaminated soil removed during the 1984 third soil clean up unknown as well?

RESPONSE

The available references do not provide any information concerning the off-site disposal location of contaminated soil from the 1984 third soil cleanup

CDH-6 COMMENT

Section 1 4 2 2 Page 1-26

Ground penetrating radar or some other kind of noninvasive geophysical investigation should be done to define the location of the 125 buried drums in Trench T-1, SWMU Ref No 108

RESPONSE

A magnetometer survey was conducted during the Phase I RI Drum locations as determined by this investigation and by visual inspection are shown in Figure 1-8

CDH-7 COMMENT

Section 1 4 3 1 Page 1-27

Again, some kind of noninvasive geophysical investigation should be done to define the location of the 300 buried drums

RESPONSE

Figure 1-8 exhibits the location of the barrels as determined by visual inspection and magnetometer survey

CDH-8 COMMENT

Section 2 0

Phase I Site Evaluation item nine, air monitoring for total long lived, alpha, plutonium, and volatile organics during field activities is listed, however, the collection and analytical methods should also be referenced for evaluation

RESPONSE

A discussion has been added to Section 2 3 6 (see pp 2-81 through 2-86) describing the field air monitoring conducted during the Phase I site evaluation including the sampling protocols and results

CDH-9 COMMENT

Table 2-3

Regarding radiological parameters, the results for sediments should be in pCi/gram, not pCi/liter

RESPONSE

Table 2-5 (previously Table 2-3) has been corrected to show picoCuries per gram (pCi/g) as the unit for sediment radiological parameter results

CDH-10 COMMENT

Table 2-4

Are the radiological parameter results to be in pCi/l or pCi/g?

RESPONSE

Table 2-6 (previously Table 2-4) has also been corrected to show pCi/g as the unit for radiological parameter results

CDH-11 COMMENT

Section 2.3.1 Page 2-14

It is not an acceptable practice to use background concentrations derived from maximum detectable values i.e. sample size less than seven and in some cases as few as two samples, to identify contaminated sites. It is acceptable to use maximum background values for borehole and monitoring well placement. All background concentrations used to identify contaminated sites must be within 95% upper tolerance interval limits, or 95% or higher upper confidence interval limits.

RESPONSE

Maximum detected background values are used for comparison with site-specific data when tolerance intervals are not available. The text in Section 2.3.1 (see p 2-18) has been modified to state that tolerance intervals will be used to assess the presence of contamination, whereas site-specific chemical concentrations above the maximum detected background values will be considered a preliminary indication of contamination.

CDH-12 COMMENT

Section 2.3.2.1 Page 2-28

No reference to HASL-235 et seq documentation. There is no mention of the work done by Michels (RI) who did work on the depth of soil contamination penetration in the 903 Area. Michels also published information regarding background Pu in the midwest for comparison with the RFP environs.

RESPONSE

HASL-235 is a document prepared by P W Krey and E P Hardy of the AEC HASL on August 1, 1970. The report references the work of Dr Martell. Following a serious fire at Rocky Flats on May 11, 1969, Dr Martell demonstrated the presence of plutonium-239 in soil around the Plant. Subsequent to this discovery, HASL was invited to perform a study of the plutonium-239 distribution in soil around the Plant. The HASL study was also designed to determine the source, quantity, and extent of Rocky Flats plutonium off AEC property.

The investigation findings indicated that leaking barrels of plutonium-laden cutting oil stored in the southeast corner of the Plant (903 Drum Storage Area) were the likely source of the offsite plutonium. This conclusion was made based on historical wind behavior patterns, release estimates, and concentration contour configurations.

The HASL-235 does not mention any work conducted by Michels nor does it present any information on soil sampling beneath the 903 Pad or background plutonium concentrations in the midwest

CDH-13 COMMENT

Section 2.3.2 1 Page 2-31

The reduction of Pu/Am contamination by wet screening is suspect While Pu attaches to clay particles and particle size separation (a soils classification methodology used by USGS and Dr Johnson) is feasible, there are complications The wet process takes considerable water and total destruction of the particle conglomerates The treatment and disposal of such waste water would present additional complications Dry separation is also problematic due to the dust generated even with closed systems Cleveland (RI now USGS) tried the process using clean soil unsuccessfully at the Sweeny Mining and Milling facility on Sugarloaf above Boulder

RESPONSE

The reference in Section 2 3 2 1 (see p 2-31) to the use of wet screening for the reduction of plutonium and americium soil contamination below the 903 Pad is cited as a conclusion drawn from a study conducted by Navratil (1979) Wet and dry separation methods will be thoroughly evaluated during the CMS/FS

CDH-14 COMMENT

Section 2 3 2.2 Page 2-37

The 903 Drum Storage area has been identified as the wind dispersal source of ground surface plutonium and americium contamination at the Mound, Oil Burn Pit and Trench Sites There should be a meteorological analysis of the direction of prevailing winds over the site with respect to topography Were there topographical features where winds could have deposited significant amounts of radionuclide contaminated soil before the pad was placed on 903?

How many additional soil samples will be collected from borings at both possible Pallet Burn Sites? Will the soil sampling tests and data needed to evaluate depth and extent of plutonium in soils at both Pallet Burn sites be completed and presented in the Draft phase RI Plan?

RESPONSE

A meteorological analysis along with the plutonium/americium profile data will be used in substantiating or refuting the theory that the 903 Drum Storage Area is the source of surficial soil plutonium and americium contamination The results of the investigation will be presented in the draft Phase II RFI/RI Report

The proposed boreholes for the Phase II field investigation are discussed in Section 5 3 2 of the work plan along with an explanation of the sampling methodology As discussed in this section, the possible western location for the Pallet Burn Site is inaccessible, and therefore, additional borings are not proposed An additional borehole (BH2891) will be drilled in the possible eastern location to aid in evaluating the site boundary All soil analytical results will be provided in the draft Phase II RFI/RI Report

CDH-15 COMMENT

Section 2.3.2 Soils

What radionuclides, other than americium and plutonium will be tested for in evaluation of elevated Pu and Am concentration in surface soils?

RESPONSE

Surficial soil samples and vertical profile samples will be analyzed for plutonium-239+240 and americium-241, uranium-233+234, uranium-235, and uranium-238 as discussed in Section 5.4. Boreholes drilled to characterize IHSSs will be sampled for the full suite of radionuclides presented in Table 5-3.

CDH-16 COMMENT

Section 2.3.2.1

903 Pad & Lip Sites Ph I RI Soil Investigation Results How many and where, will the additional boreholes, through and immediately adjacent to the pad during Phase II RI validation of VOC soil contamination be placed?

Page 2-35 Specify what additional surficial soil and soil profiling is going to characterize the radionuclide distribution on the 903 Pad and Lip Sites

RESPONSE

The proposed boreholes for further investigation of the 903 Pad Area are presented in Section 5.3.1. Thirteen borings are proposed within and adjacent to the pad to characterize the vertical and horizontal extent of radionuclide and solvent contamination.

Section 5.4 provides a discussion of the surficial soil sampling and profile sampling program to be conducted for the Phase II investigation. Soil samples for plutonium, americium, and uranium will be collected from 122 grids (surface scrapes). Also, vertical profiles of these radionuclides to a depth of one meter will be determined at 22 locations. The sampling locations are near the 903 Pad, Mound, and East Trenches Areas and in the buffer zone to Indiana Street.

CDH-17 COMMENT

Section 2.3.2.3 Page 2-38

Page 2-39 What was the depth of the uppermost soil sample taken at Borehole BH 52-87, where the most contaminated soil was found?

RESPONSE

The uppermost soil sample taken at borehole BH52-87 was composited from 0 to 9.5 feet below ground surface (see p. 2-41).

CDH-18 COMMENT

Section 2.3.3.1 Page 2-42

Will the CCl₄ plume at 903 Pad be sufficiently delineated by information gained from the additional boreholes placed immediately adjacent to the pad, referred to in Section 2.3.2.1 for VOC soil contamination Ph II RI Validation?

Page 2-48 How many and where will the additional monitoring wells to delineate the extent of PCE contamination, (southeast downgradient of the 903 Pad and Trench T-2), be placed?

Page 2-49 How will the additional data required to assess the significance of chloroform in wells 28-87 and 30-87 be gathered?

Page 2-50 What further sampling and analysis will be done to resolve methylene chloride and acetone contamination at well 36-87BR?

RESPONSE

Eighteen new alluvial monitoring wells are proposed to further define the extent of volatile organics in the shallow ground-water system east and southeast of the 903 Pad Area. Thirteen boreholes are proposed within and immediately adjacent to the 903 Pad to characterize the vertical and horizontal extent of both solvent and radionuclide contamination beneath the pad. Samples from the proposed monitoring wells and boreholes for the Phase II investigation should provide sufficient information to delineate the carbon tetrachloride plume in the 903 Pad Area as well as determining the extent of solvent contamination in the soils beneath the pad.

Section 5.2.1.1 provides a discussion of the number and location of proposed alluvial monitoring wells for the 903 Pad Area. A total of eighteen new wells will be installed during Phase II to aid in defining the extent of volatile organic in ground water in the 903 Pad Area.

In order to assess the significance of the isolated reports of chloroform in wells 28-87 and 30-87, additional monitoring of these wells will be conducted and additional monitoring wells will be installed in unweathered sandstones in the area. This work will be conducted during the Phase II bedrock investigation as outlined in the Phase II RFI/RI Work Plan (bedrock).

Well 36-87 will continue to be sampled during the quarterly sampling program. The additional methylene chloride and acetone data will provide the necessary information to determine if the previous reports of these analytes in well 36-87 represent actual contamination or are laboratory artifact.

CDH-19 COMMENT

Section 2.3.6 Page 2-81

The ambient air data is not provided by individual station, which is important, as the individual station data of significance is washed out in averaging. The resultant summary talks in generalities only. There is a need to require historical air sampling data as current concentrations are lower, due to surficial burial of the contamination.

RESPONSE

Site specific air monitoring results are now presented in Section 2.3.6 of the revised work plan (see pp 2-8 through 2-86). All data collected as part of the Radioactive Ambient Air Monitoring Program (RAAMP) are reported monthly by individual site. These data are available in the Rocky Flats Plant Monthly Environmental Monitoring Reports.

CDH-20 COMMENT

Page 2-84

The last sentence refers to airborne plutonium contamination as being in compliance with Clean Air Act regulations (40 CFR 61). Subpart H of 40 CFR 61 is the National Emission Standard for Radionuclide Emissions from Department of Energy (DOE) facilities. This covers radionuclide emissions as a whole and not specifically for plutonium as implied in the document. There are no specific standards for plutonium in the CFR or State Regulations.

RESPONSE

The text has been modified to remove the implication that there are specific standards for plutonium in the Code of Federal Regulations (CFR) or state regulations (see p 2-85).

CDH-21 COMMENT

Section 2.3.8 Page 2-85

The summary of contamination only addresses ground water. There are no statements regarding soil contamination.

RESPONSE

This section has been modified to cite the principal contaminants in each environmental media.

CDH-22 COMMENT

Section 2.4

Applicable or Relevant and Appropriate Requirements should also include a reference to the Colorado Clean Air Act and the Air Quality Control Commission's (AQCC) Regulations. The AQCC regulations are especially important for considerations of complete or partial removal and treatment of wastes and contaminated soils, which are again referred to in Section 2.5. The regulations also apply for in-situ treatment.

RESPONSE

ARARs addressing contaminants in air will be addressed in the CMS/FS Report. In general, federal and state standards for air exist only as source- or activity-specific requirements and, accordingly, will be addressed in detail in the FS process.

CDH-23 COMMENT

Section 2.4 Page 2-87 to 2-95 Table 2-12

Table 2-12 and Section 2.4 on ARARs addresses water only. No mention of ARARs for soil and sediment contamination for radiological and hazardous substances

Table 2-12 starting on Page 2-89 lists ARARs which I understand were based on ground water standard or surface water drinking standards or other appropriate standards but did not specifically list as potential standards the site specific surface water standards based on aquatic life uses -- I assume because there would be no aquatic life use of "ground water". However, I believe both sets of standards should be listed because

- a) pages 2-87 of the document states there is "significant interaction of alluvial ground water and surface water in the drainages of the Rocky Flats Plant", and**
- b) any discharge to the surface waters, e.g., during remediation, must meet the surface water standards, and these surface water standards could be more stringent than the presently identified ARARs (i.e., aquatic life standards for metals can be significantly more restrictive than drinking water standards)**

Many of the standards for surface water metals are listed as Table Value Standards (TVS) referring to formulas in the Basic Standards which are based on hardness as CaCO_3

Page 2-89 The effective site specific surface water standard for chloroform is 1.0 micrograms per liter (based on detectable levels)

The detection level specified by CDH for tetrachloroethene and 1, 1, 2, 2-tetrachloroethane is 1.0 microgram per liter, not 5

Page 2-93 Typo It should state "Analytical results are total nitrate plus nitrite nitrogen"

Page 2-94 The units should be pCi/liter for rad, rather than mg/liter, and the gross alpha ARAR is CDH surface water standard (not ground water)

RESPONSE

The discussion of ARARs has been substantially revised and may now be found in Section 7.0. Included in the revisions was the development of an ARAR table addressing ground water only. Standards considered in the development of ARARs for ground water included those found in the Safe Drinking Water Act (SDWA) and RCRA 40 CFR Part 264 Subpart F. Other references were reviewed for the ground-water medium as items TBC.

There are no chemical specific ARARs for soils. Acceptable concentrations will be determined through a risk assessment, which the ARARs section now discusses (Section 7.6).

Surface water stations have been determined to be outside the boundaries of OU No. 2, with the exception of ground-water seeps. For this work plan, seeps are regarded as points at which ground-water quality may be characterized. Surface water investigations, including investigating the influence of seeps on surface water quality, are the subject of other Operable Unit remedial investigations (OU Nos. 5 and 6). Accordingly, no discussion of ARARs for surface water has been presented in this work plan.

Detection limits used in this work were established based on the GRRASP, EG&G Rocky Flats, February 15, 1990. There are currently no CDH-practical quantitation limits (PQLs).

The correct units for radionuclides is picoCuries per liter (pCi/l) The revised table (Table 7-1) reflects this correction Proposed ARAR standards presented in the revised text are for ground water, as discussed above

CDH-24 COMMENT

Table 2-13 Page 2-96

Response actions and remedial technologies should include controls of air emissions for study and review

RESPONSE

Table 2-17 (previously Table 2-13) provides an overview of general response actions and applicable technologies and is not intended to provide details of secondary waste generation or air emission controls The need for and effectiveness of air emission controls will be evaluated for all technologies that generate air pollutant emissions

CDH-25 COMMENT

Page 3-7 Table 3-2

Are the units in mg/liter or pCi/l for radiological parameters? The table does not address soil or sediments

RESPONSE

Table 3-2 in the April 12, 1990 submittal provided redundant information relative to Table 2-13 and therefore has been deleted

CDH-26 COMMENT

Section 4.0

The author of this section has provided a well written concise outline of the work ahead

RESPONSE

No response required

CDH-27 COMMENT

Section 4.1.7 Page 4-14

The four methods proposed for treatability study sound interesting and promising

RESPONSE

Please note this section has been modified to address all on-going treatability study programs applicable to contamination at OU No 2

CDH-28 COMMENT

Section 5.0

The Division realizes that the site wide Health and Safety Analysis, Quality Assurance, Prevention of Contaminant Dispersion and Sampling and Analysis documents have not been submitted for review at this time Inclusion of the relevant parts of these documents is appropriate

It appears that some of the earlier comments on additional sampling were premature

RESPONSE

The Inter-agency Agreement (IAG) specifies that the Sampling and Analysis Plan (SAP) is to include a Quality Assurance Project Plan (QAPJP) and Standard Operating Procedure (SOP) for all field activities A draft QAPJP for site-wide RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) activities was submitted to the regulatory agencies in August 1990 A GRRASP has already been prepared which is the scope of work for analytical services The current Rocky Flats Plant SOPs were submitted to EPA and CDH in August 1990 The Environmental Restoration Health and Safety Project Plan (ERHSPP) is in final form On August 1990 a draft of the document was submitted to the regulatory agencies for review The Department of Energy (DOE) revised the plan based on regulatory agency comments and resubmitted a final document to the agencies for final review A site-specific Health and Safety Plan (SSHSP) defining the protocol for protection of field workers during Phase II operations will be submitted as well After finalization and approval of the work plan, the ERHSPP and OU No 2 SSHSP will not undergo formal public review, but will be available to the public A draft Prevention of Contaminant Dispersion (PPCD) was completed in September 1990 and is currently being reviewed by EPA and CDH The PPCD will be available for public review and comment on 1 March 1991 per the draft IAG schedule

CDH-29 COMMENT

Page 5-30

Don Michels in the 1970s identified that the plutonium contamination had penetrated to at least 8 cm There is not enough detail presented to concur in the sampling approach The proposal is not definitive Pu contamination identified at BH30-87 is at depths greater than 20 feet Inventory sampling procedures will yield much greater than 2 dpm/gram all the way to Indiana Street Depth profile (inventory) soil sampling data needs to be presented in $\mu\text{Ci}/\text{m}^2$ or mCi/km^2 for comparisons with historical information and materials balance (there has been no mass wasting or erosion and removal from these large areas)

RESPONSE

Surficial soil radionuclide contamination at OU No 2 will be investigated by collecting 122 surficial soil scrapes (1/8" depth) and sampling from 22 vertical soil profiles The vertical profile samples will extend below the depth of 8 cm Profile soil sampling analytical results will be presented in microCuries per

square meter ($\mu\text{Ci}/\text{m}^2$) or mCi/km^2 in the draft Phase II RFI/RI Reports for comparison with historical information

CDH-30 COMMENT

Figure 5-5

Needs a profile sample due east at Indiana Street due to the windstrewn field in that area

RESPONSE

A sampling location for an additional profile sample has been added in the area of the intersection of the Rocky Flats Plant east access road with Indiana Street (Figure 5-2, previously Figure 5-5)

CDH-31 COMMENT

Section 5 2 3 Page 5-43

This section needs uranium analysis data included Regarding the East Trenches data, all BH 53-87 2-3 5 feet deep analyses 0 98 pCi/gram, which is in excess of the State soil standard

RESPONSE

Uranium 233 + 234, 235, and 230 do not appear to be contaminants of surficial soils unlike plutonium and americium. Uranium contamination at specific IHSSs will be assessed from borehole soils data where the full suite of radionuclides will be analyzed (Table 5-2). Boreholes to be drilled into IHSSs will extend from the ground surface to the base of weathered bedrock. Continuous samples will be collected for geologic descriptions for the entire borehole depth. From this core, discrete samples will be submitted for laboratory chemical analyses every two feet from the ground surface to the water table. In addition, a discrete sample will be collected for chemical analysis at the water table. Core from saturated surficial materials will not be submitted to the laboratory, as the presence of water in this zone will affect interpretation of chemical results. In order to prevent alluvial ground water from affecting weathered bedrock samples, surface casing will be grouted into the borehole through surficial materials. Subsequent to grout hardening, the borehole will then be advanced through weathered bedrock with continuous sampling. Discrete samples from the core will be submitted to the laboratory for chemical analysis from two feet immediately below the casing and every four feet thereafter to the base of weathering. Section 5 2 3 has been deleted because the information concerning surficial sampling is provided in Section 5 1 3.

CDH-32 COMMENT

Appendix D

The appendix does not include soil or sediment ARARs

RESPONSE

The appendices provide analytical results only. The discussion of ARARs is presented in Section 7 0.

EXPLANATION



INDIVIDUAL HAZARDOUS SUBSTANCE
SITE AND FHS DESIGNATION



LOCATION OF BARRELS DETERMINED BY
VISUAL INSPECTION OR MAGNETOMETER
SURVEY



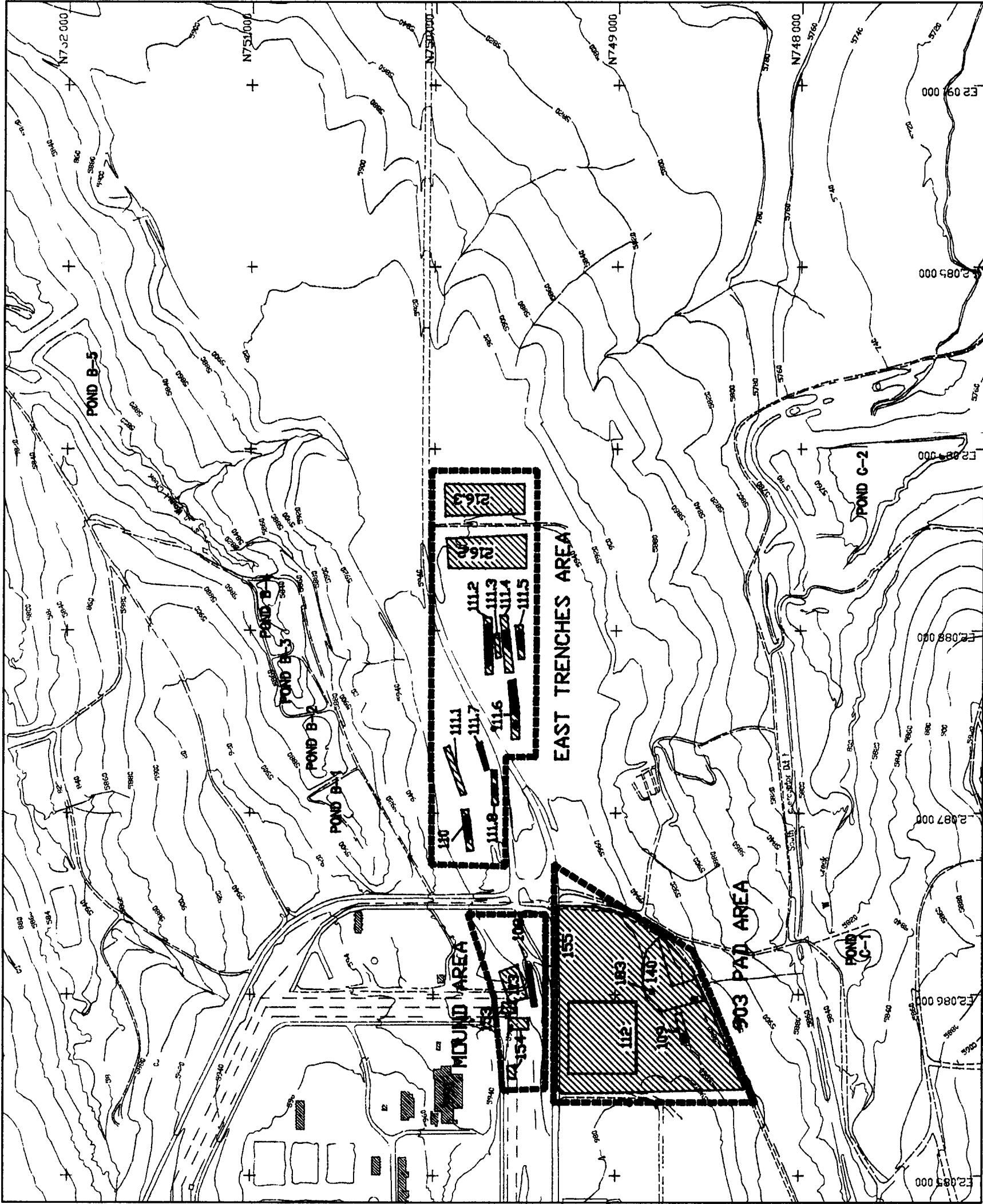
SOURCE AREAS



Scale 1" = 600'



CONTOUR INTERVAL = 20'



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II REMEDIAL WORK PLAN (ALLUVAL)

REMEDIAL INVESTIGATION AREAS AND
INDIVIDUAL HAZARDOUS SUBSTANCE
SITES

FIGURE 1-8

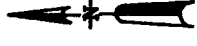
February, 1991

EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITE
AND HSS DESIGNATION



- 3217489 ● BEDROCK MONITOR WELL
- 3213789 ○ ALLUVIAL MONITOR WELL
- 0392 ▲ PRE-1986 MONITOR WELL
- 3217389 + ABANDONED HOLE
- 3H4987 ○ BOREHOLE



Scale 1" = 600'



CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

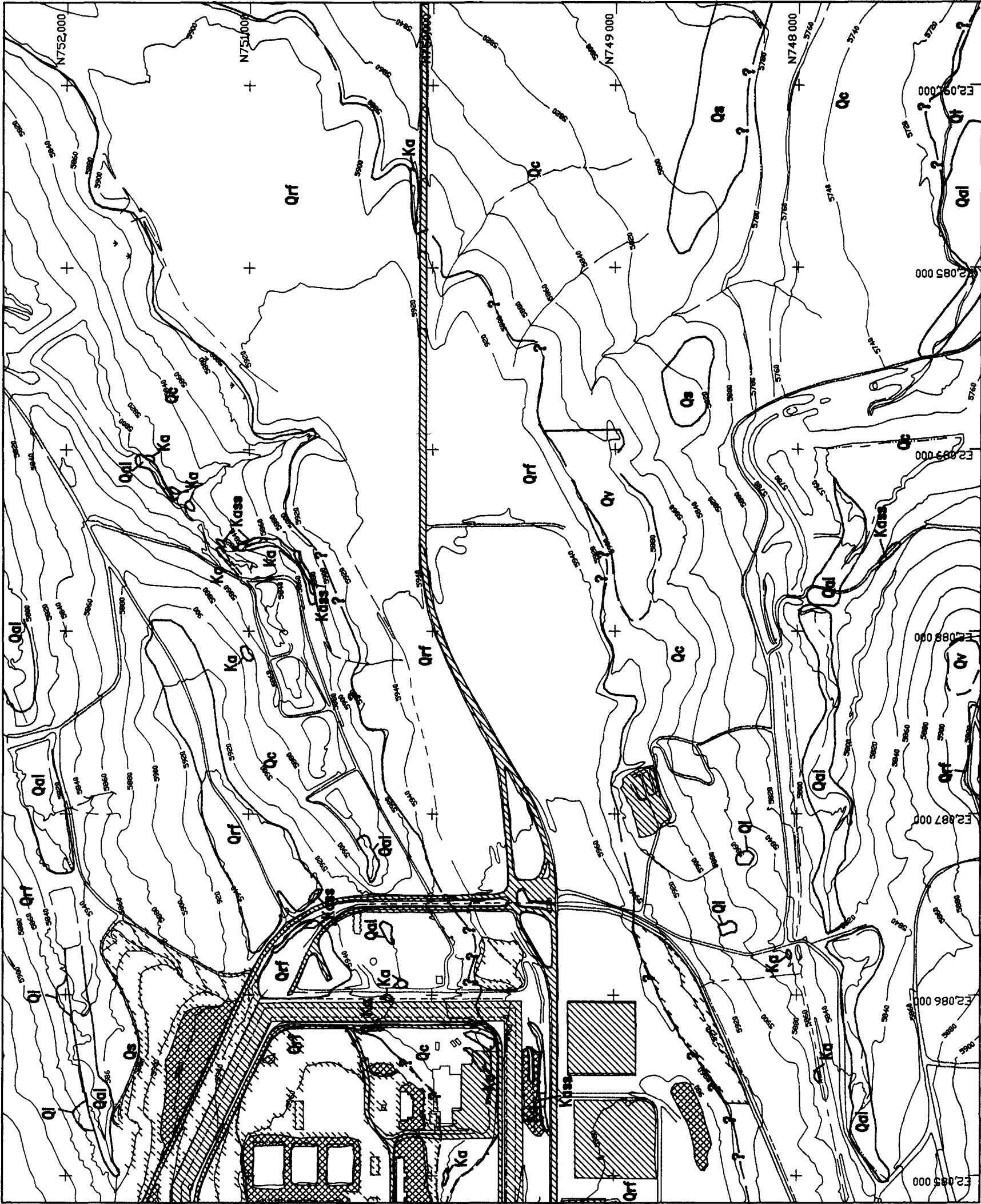
OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

PHASE I REMEDIAL INVESTIGATION
MONITOR WELL AND
BOREHOLE LOCATIONS

FIGURE 2-1

February, 1991





EXPLANATION



CONTACT
DASHED WHERE APPROXIMATELY LOCATED,
QUERIED WHERE INFERRED.



ARTIFICIAL FILL



PAVEMENT OR GRAVEL



DISTURBED GROUND

QUATERNARY

RECENT VALLEY FILL

LANDSLIDE

COLLUVIUM

TERRACE ALLUVIUM

SLOOUM ALLUVIUM

VEROOS ALLUVIUM

ROCKY FLATS ALLUVIUM

Qal

Qi

Qc

Qf

Qs

Qv

Qrf

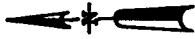
CRETACEOUS

ARAPAHOE FORMATION, SANDSTONE

ARAPAHOE FORMATION, CLAYSTONE

Kass

Ka



Scale 1" = 600'



CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

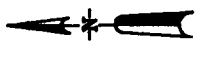
SURFICIAL GEOLOGY

FIGURE 2-2

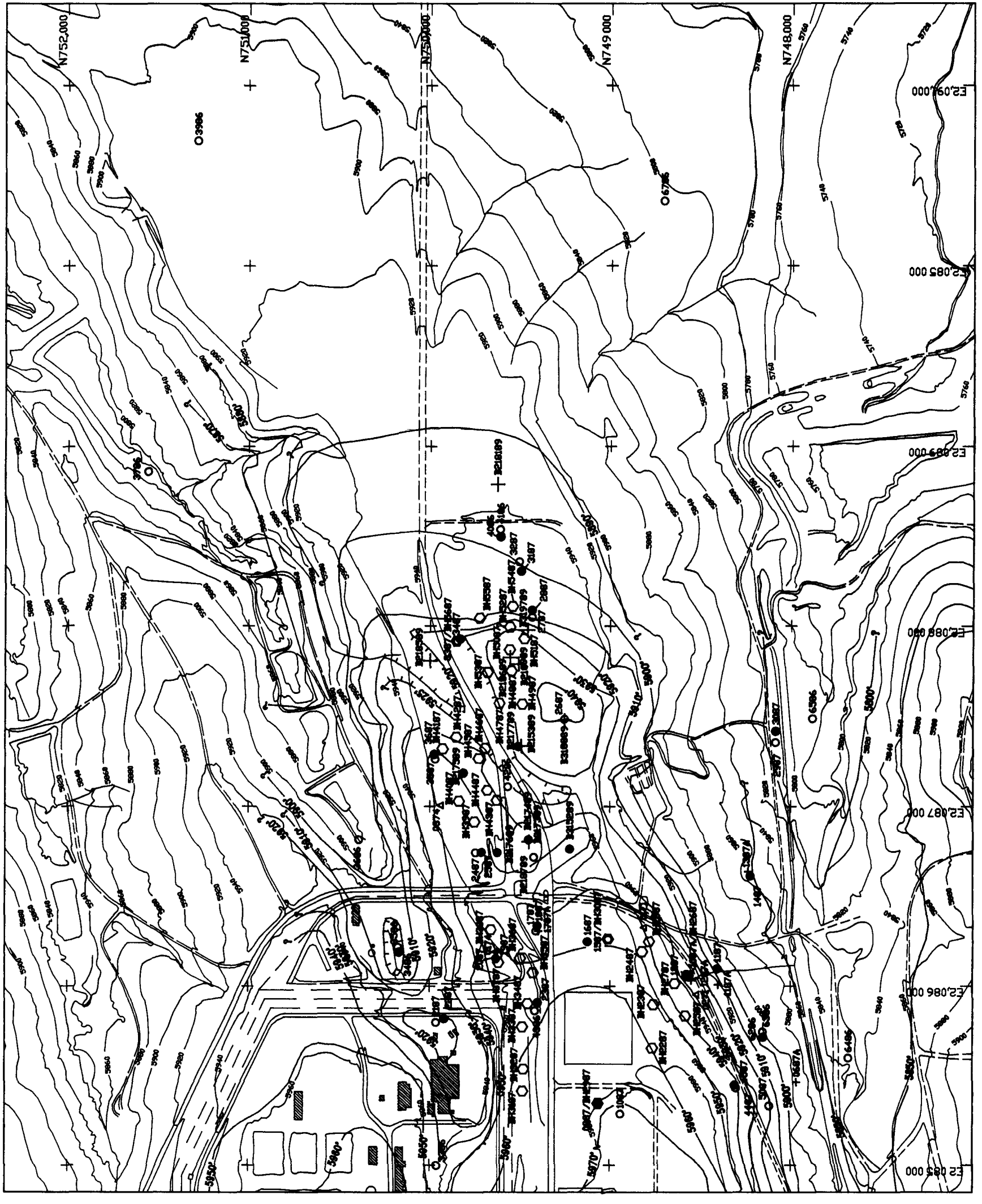
February, 1991

EXPLANATION

- 5900 — TOP OF BEDROCK ELEVATION (FEET ABOVE M.S.L.)
CONTOUR INTERVAL VARIES
QUERIED WHERE INSUFFICIENT DATA
- BEDROCK MONITOR WELL
- ALLUVIAL MONITOR WELL
- △ PRE-1986 MONITOR WELL
- + ABANDONED HOLE
- BOREHOLE



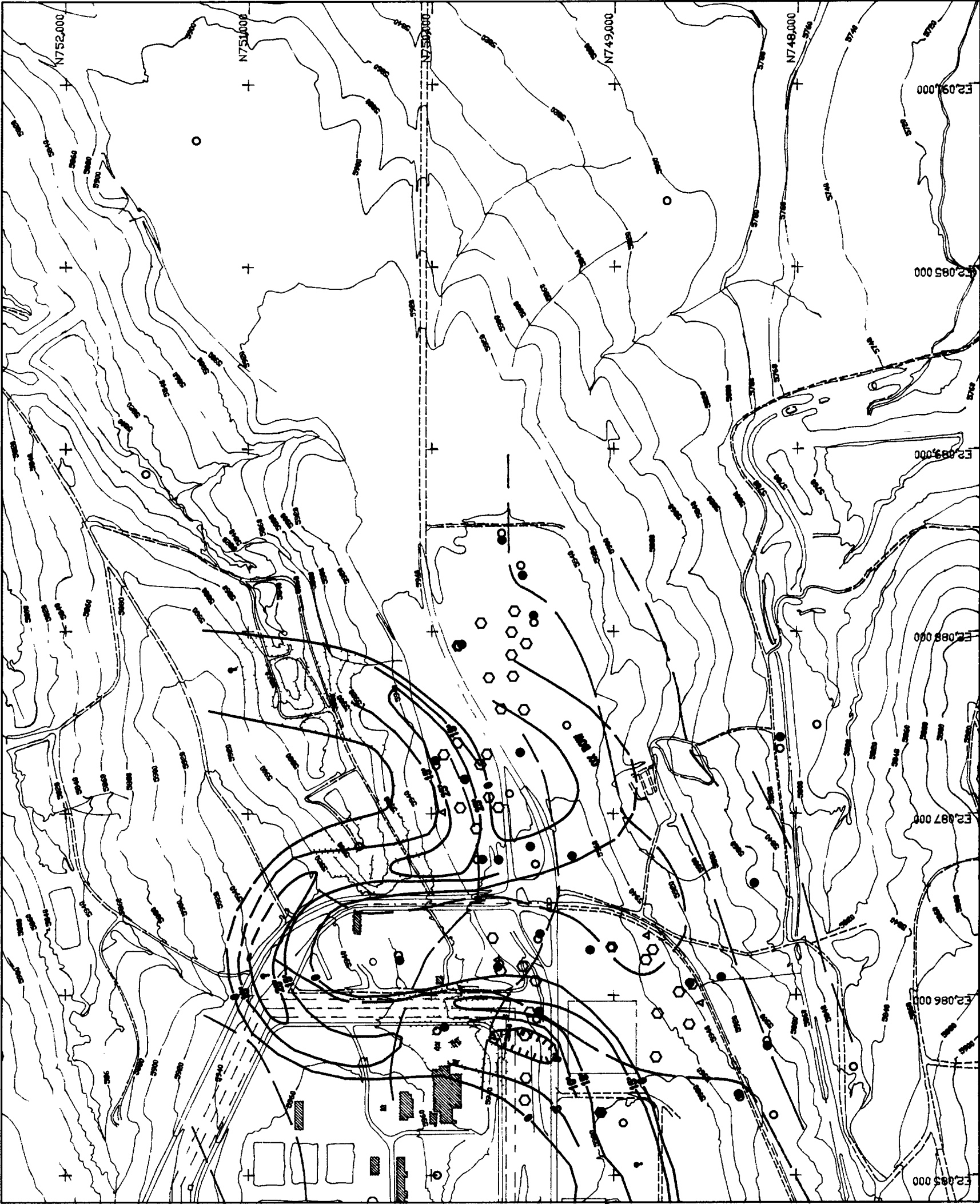
Scale 1 = 600
0' 300' 600'
CONTOUR INTERVAL = 20'



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

OPERABLE UNIT NO 2
PHASE II RT/RI WORK PLAN (ALLUVIAL)

TOP OF BEDROCK ELEVATION



EXPLANATION

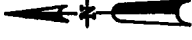
- BEDROCK MONITOR WELL
- ALLUVIAL MONITOR WELL
- △ PRE-1986 MONITOR WELL
- BOREHOLE

PORTION OF CHANNEL REMOVED BY EROSION

ISOPACH OF ARAPAHOE SANDSTONE #1
DASHED WHERE APPROXIMATELY LOCATED,
QUERIED WHERE INFERRED

ESTIMATED LATERAL EXTENT OF ARAPAHOE
SANDSTONE #3
DASHED WHERE APPROXIMATELY LOCATED

ESTIMATED LATERAL EXTENT OF ARAPAHOE
SANDSTONE #4
DASHED WHERE APPROXIMATELY LOCATED



Scale 1 = 600



CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

ESTIMATED LATERAL EXTENT OF
ARAPAHOE FORMATION SANDSTONES
1, 3, AND 4

FIGURE 2-4

February, 1991

EXPLANATION



INDIVIDUAL HAZARDOUS SUBSTANCE SITE (HSS)

5798

POTENTIOMETRIC SURFACE ELEVATION (feet above mean sea level)

ALL DATA BASED ON MEASUREMENTS MADE APRIL 4-8, 1988 INCLUSIVE

LINE OF EQUAL POTENTIOMETRIC SURFACE ELEVATION (feet above mean sea level)—DASHED WHERE APPROXIMATELY LOCATED

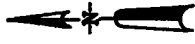
5860

NO DATA

3217489 ● BEDROCK MONITOR WELL

3213789 ○ ALLUVIAL MONITOR WELL

0382 ▲ PRE-1988 MONITOR WELL



Scale 1" = 600'



CONTOUR INTERVAL = 20'

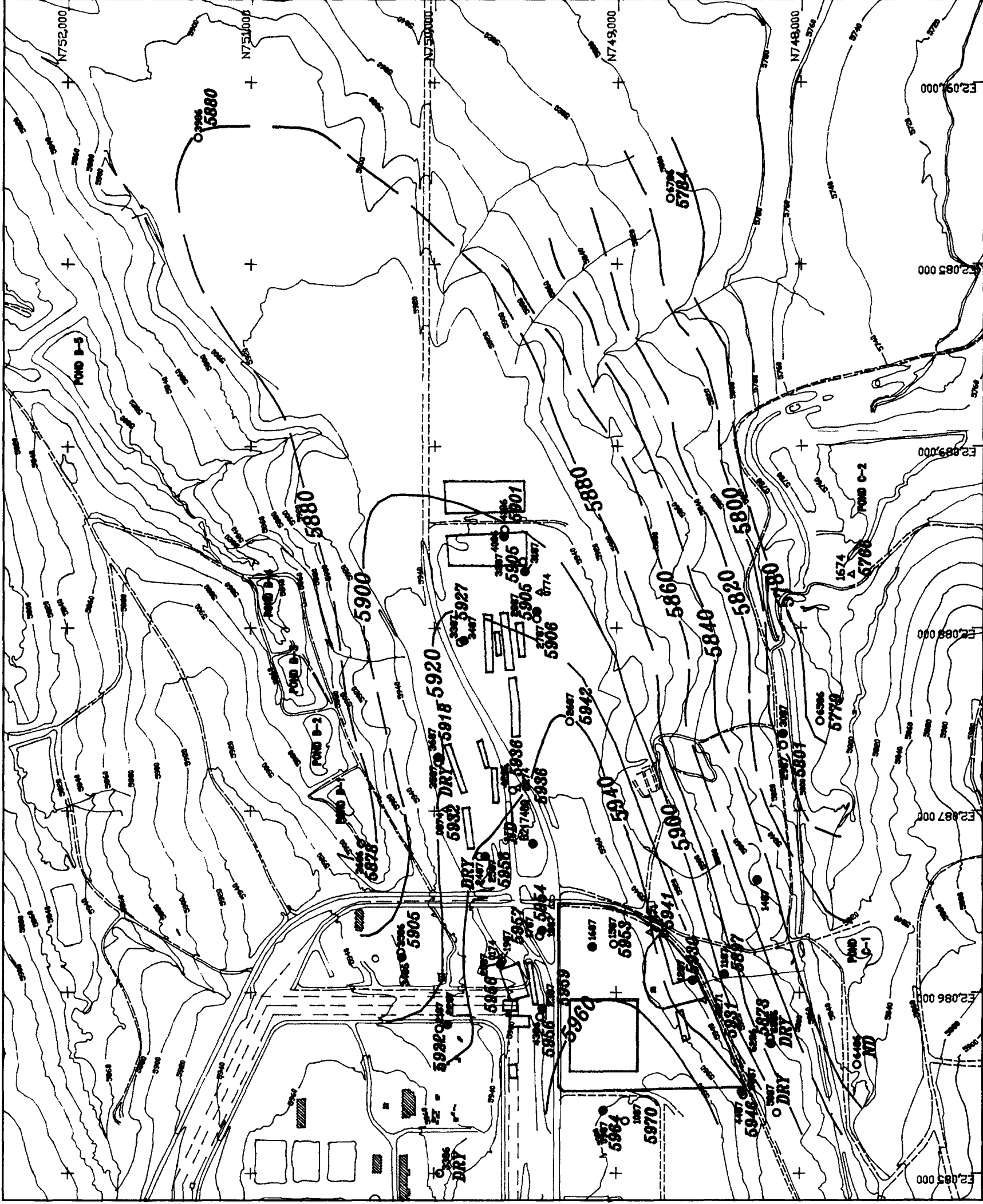
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II REF/RI WORK PLAN (ALLUVIAL)

POTENTIOMETRIC SURFACE OF THE
UPPER HYDROSTRATIGRAPHIC
GROUND-WATER FLOW SYSTEM

FIGURE 2-5

February, 1991





EXPLANATION



SOIL TYPE BOUNDARY AND NUMBER

SOURCE: U.S. DEPARTMENT OF AGRICULTURE, 1980

SOIL TYPE NUMBER

SERIES

27	DENVER
28	DENVER-KUTCH
31	DENVER-KUTCH-MIDWAY
42	ENGLEWOOD
45	FLATIRON
60	HAVERTON
80	LEYDEN-PRMEN-STANDLEY
98	MIDWAY
100	NEIDERLAND
102	NUNN
103	STANDLEY-NUNN
148	WILLOWMAN-LEYDEN
174	



1 = 1000



CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

SURFACE SOILS MAP

FIGURE 2-6

February, 1991

EXPLANATION

**INDIVIDUAL HAZARDOUS SUBSTANCE SITE
(IHSS)**

LINE OF EQUAL CCl_4 CONCENTRATION ($\mu\text{g/l}$)
DASHED WHERE APPROXIMATELY LOCATED

NOTE. DATA VALUES SHOWN ON TABLE 2-11

BEDROCK MONITOR WELL

ALLUMAL MONITOR WELL

PRE--1986 MONITOR WELL

B217489 ●
 B213789 ○
 0382 ▲

Scale 1 = 600

600°
300°
0°

CONTOUR INTERVAL = 20'



**U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado**

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)
CARBON TETRACHLORIDE ISOPLETHS FOR
THE UPPER HYDROSTRATIGRAPHIC
GROUND-WATER FLOW SYSTEM
Second Quarter 1989

FIGURE 2-9

February, 1991

EXPLANATION

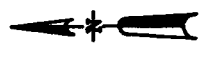


INDIVIDUAL HAZARDOUS SUBSTANCE SITE (HSS)

500

LINE OF EQUAL PCE CONCENTRATION (µg/l)
DASHED WHERE APPROXIMATELY LOCATED
NOTE: DATA VALUES SHOWN ON TABLE 2-11

- 3217489 ● BEDROCK MONITOR WELL
- 3213789 ○ ALLUVIAL MONITOR WELL
- 0382 △ PRE-1988 MONITOR WELL



Scale 1" = 600'
0' 300' 600'
CONTOUR INTERVAL = 20'

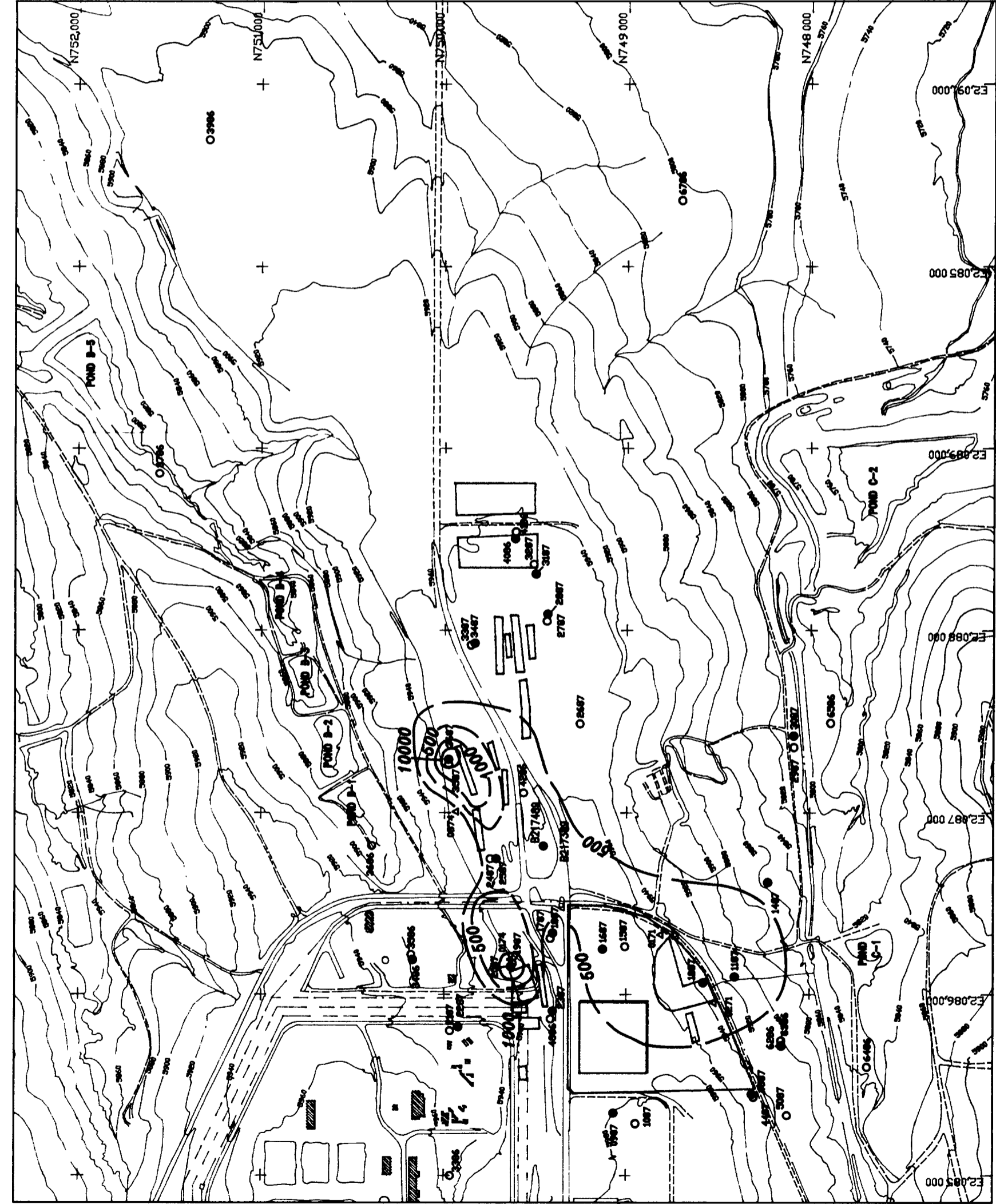
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

TETRACHLOROETHENE ISOPLETHS FOR
THE UPPER HYDROSTRATIGRAPHIC
GROUND-WATER FLOW SYSTEM
Second Quarter 1989

FIGURE 2-10

February, 1991





EXPLANATION



INDIVIDUAL HAZARDOUS SUBSTANCE SITE (HSS)



LINE OF EQUAL TCE CONCENTRATION (ug/l)
DASHED WHERE APPROXIMATELY LOCATED

NOTE: DATA VALUES SHOWN ON TABLE 2-11



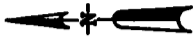
3217489 ● BEDROCK MONITOR WELL



3213789 ○ ALLUVIAL MONITOR WELL



0382 ▲ PRE-1988 MONITOR WELL



Scale 1" = 600'



CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

TRICHLOROETHENE ISOPLETHS FOR
THE UPPER HYDROSTRATIGRAPHIC
GROUND-WATER FLOW SYSTEM
Second Quarter 1989

FIGURE 2-11

February, 1991

EXPLANATION

- Contact Between Rocky Flats Alluvium and Bedrock (unconformity)
 - • • Boundary Between Upper & Lower Hydrostratigraphic Unit
 - Contamination Plume (potential)
 - Volatilization
 - Receptor
 - Groundwater Pathway (potential)
 - Storm Runoff Pathway
 - Wind Blown Pathway
 - Stream Surface
 - Groundwater Surface
- CRETACEOUS BEDROCK UNITS
- Kass Sandstone Channels
 - Kacu Unweathered Claystone/Siltstone
 - Kacw Weathered Claystone/Siltstone
- QUATERNARY ALLUVIAL UNITS
- Qrf Rocky Flats Alluvium
 - Qc Colluvium Deposits
 - Qal Stream Bed Deposits

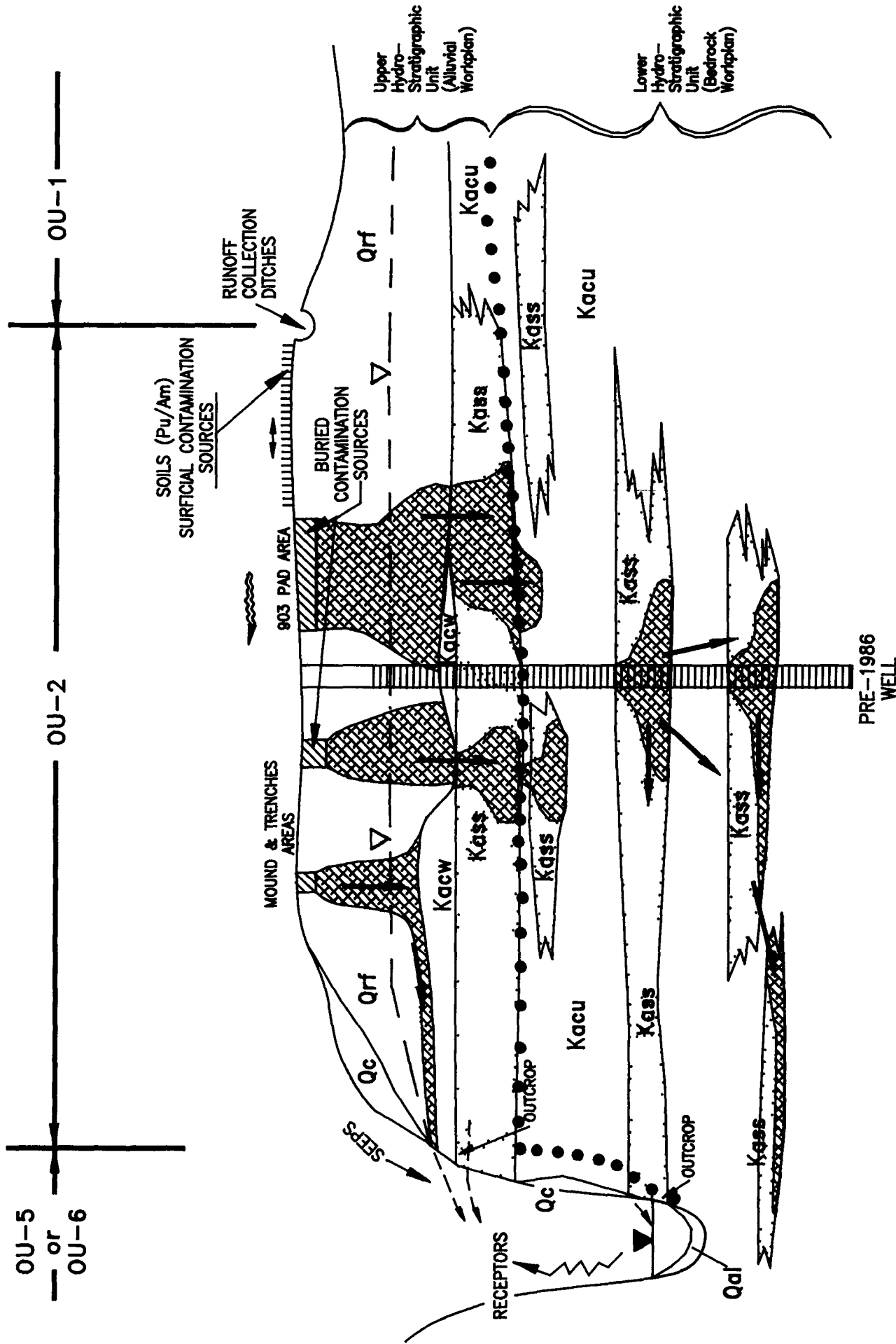
SCHEMATIC CROSS SECTIONAL VIEW
NOT TO SCALE

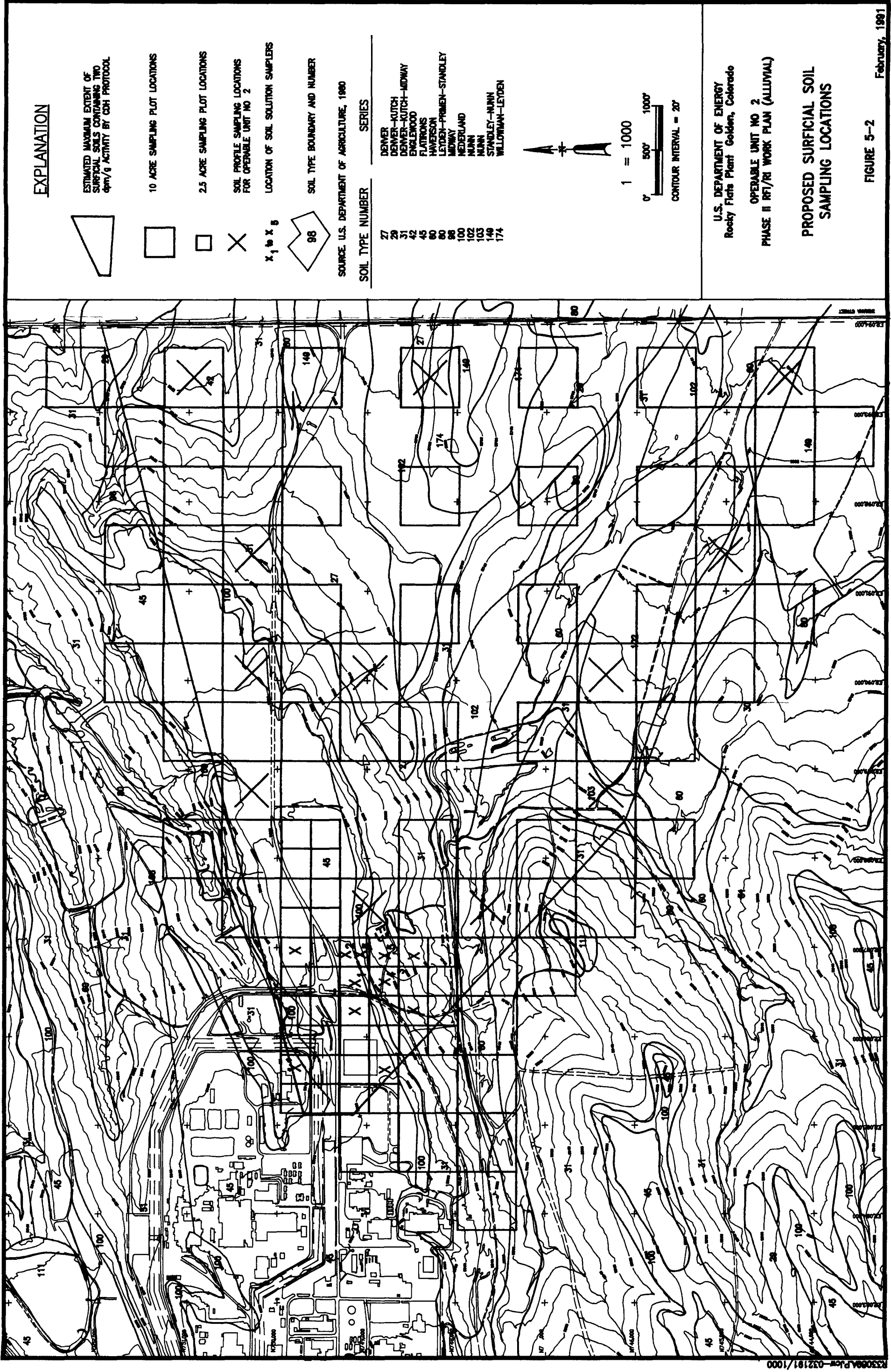
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado
OPERABLE UNIT NO 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

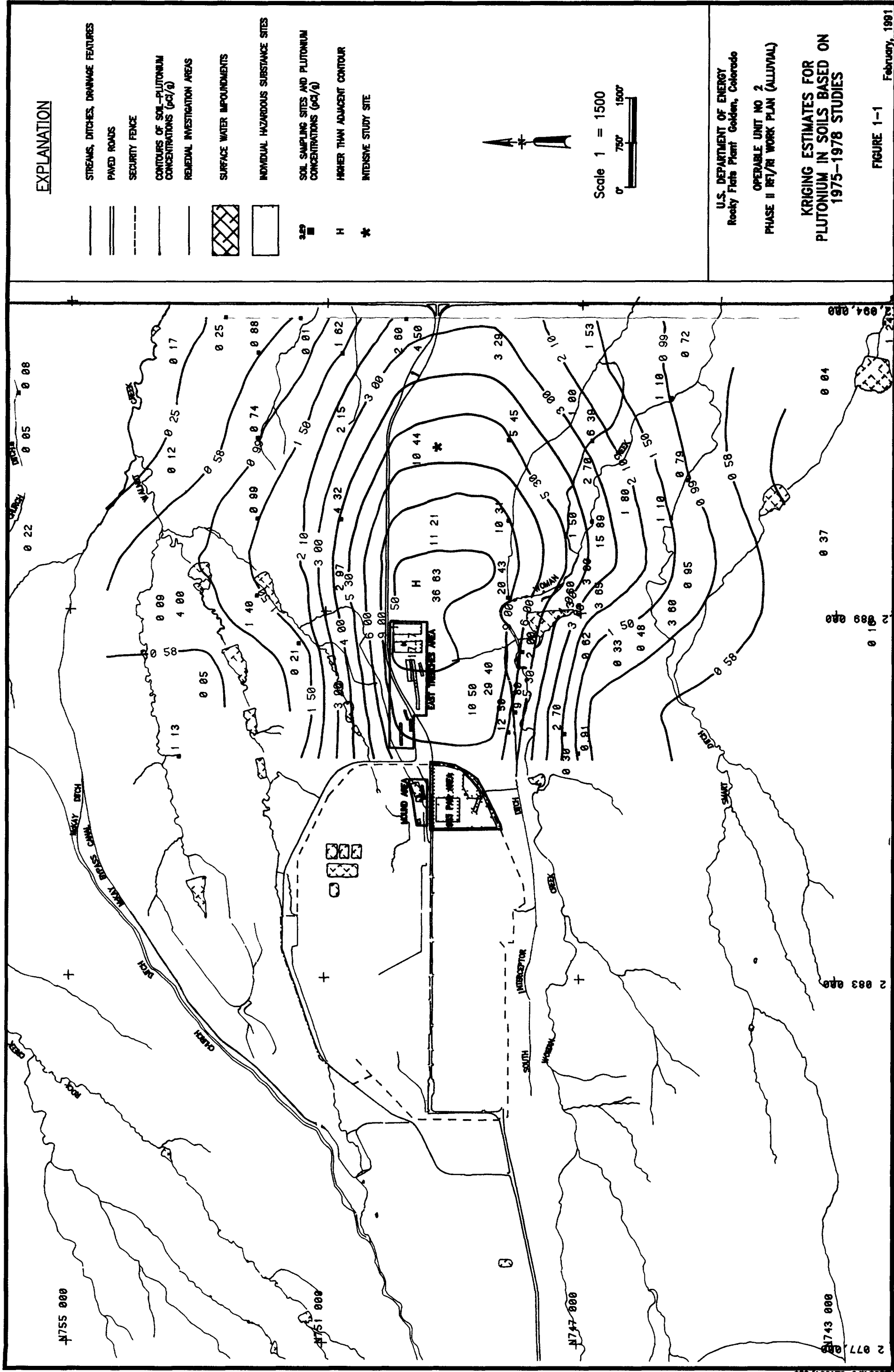
SITE CONCEPTUAL MODEL

FIGURE 2-15

February 1991







EAST TRENCHES AREA

0631 0631N

+

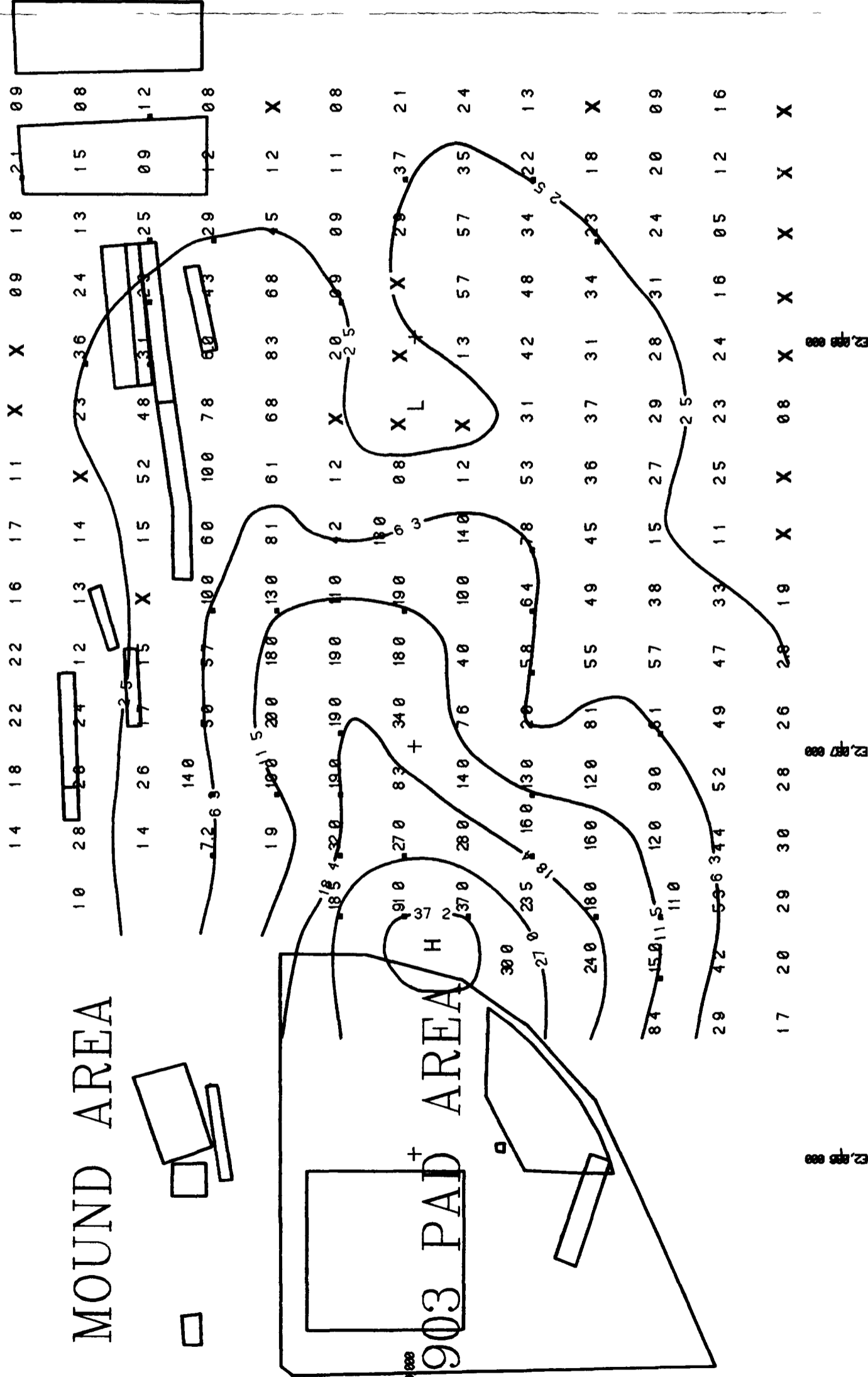
+

+

MOUND AREA

903 PAD⁺ AREA

N740-888

EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

CONTOURS OF SOIL-AMERICIUM
CONCENTRATIONS (pCi/g)

**IN SITU MEASUREMENT SITES AND
AMERICIUM 241 CONCENTRATIONS (pci/g)**

HIGHER THAN ADJACENT CONTOUR

LOWER THAN ADJACENT CONTOUR

LOCATION WHERE MEASUREMENTS WERE
LESS THAN 0.9 pCi/g

NOTE. AMERICIUM CONCENTRATIONS WERE DERIVED FROM IN SITU RADIOLOGICAL SURVEY MEASUREMENTS, (EG&G/ELM, 1990).

Scale 1 = 300

**U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado**

OPERABLE UNIT NO 2
PHASE II RFI/R1 WORK PLAN (ALLUVIAL)

KRIGING ESTIMATES FOR AMERICIUM IN SOILS BASED ON 1990 STUDIES

FIGURE 1-4

February, 1991

EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

CONTOURS OF SOIL-AMERICIUM CONCENTRATIONS (pCi/g)

IN SITU MEASUREMENT SITES AND AMERICIUM 241 CONCENTRATIONS (pCi/g)

LOWER THAN ADJACENT CONTOUR

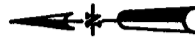
LOCATION WHERE MEASUREMENTS WERE LESS THAN 0.9 pCi/g

24

L

X

NOTE: AMERICIUM CONCENTRATIONS WERE DERIVED FROM IN SITU RADIOLOGICAL SURVEY MEASUREMENTS, (ERAG/EA, 1990).



Scale 1 = 300



U. S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

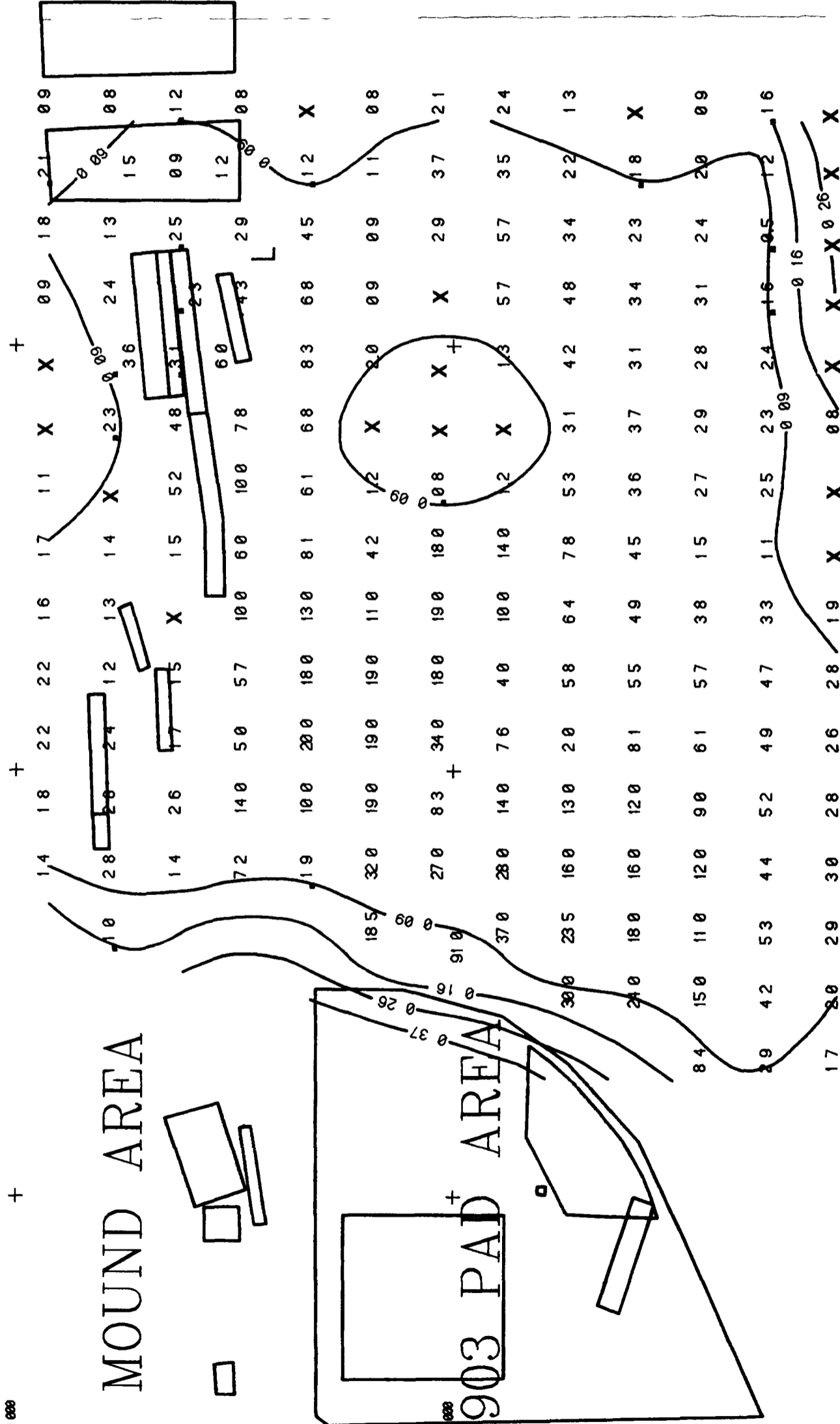
OPERABLE UNIT NO. 2
PHASE II RTI/RI WORK PLAN (ALLUVIAL)

KRIGING STANDARD OF ERROR ESTIMATES
FOR AMERICIUM IN SOILS
BASED ON 1990 STUDIES

FIGURE 1-5

February, 1991

EAST TRENCHES AREA



82, 83, 84

88, 89, 90

N750 000

N740 000

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITES
- CONTOURS OF SOIL-PLUTONIUM CONCENTRATIONS (pCi/g)
- IN SITU MEASUREMENT SITES AND PLUTONIUM CONCENTRATIONS (pCi/g)
- HIGHER THAN ADJACENT CONTOUR
- LOWER THAN ADJACENT CONTOUR
- LOCATION WHERE MEASUREMENTS WERE LESS THAN 0.9 pCi/g

NOTE: PLUTONIUM CONCENTRATIONS WERE DERIVED FROM AMERICIUM CONCENTRATIONS WHICH IN TURN WERE DERIVED FROM IN SITU RADIOLOGICAL MEASUREMENTS (EG&G/EM, 1990).



Scale 1 = 300



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

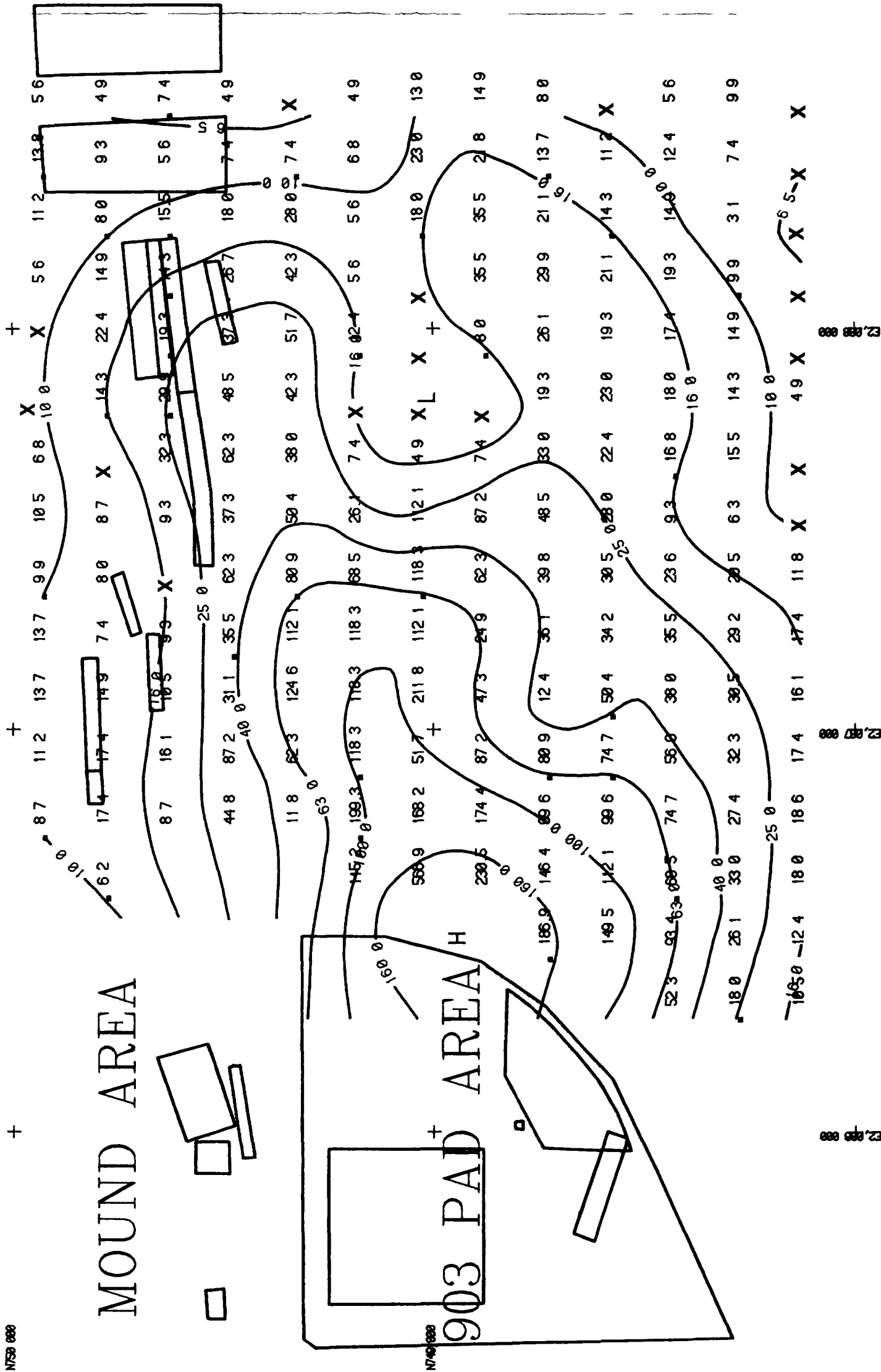
OPERABLE UNIT NO 2
PHASE II RET/RI WORK PLAN (ALLUVAL)

KRIGING ESTIMATES FOR
PLUTONIUM IN SOILS
BASED ON 1990 STUDIES

FIGURE 1-6

February, 1991

EAST TRENCHES AREA



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

CONTOURS OF SOIL-PLUTONIUM CONCENTRATIONS (pci/g)

IN SITU MEASUREMENT SITES AND PLUTONIUM CONCENTRATIONS (pci/g)

LOWER THAN ADJACENT CONTOUR

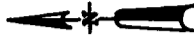
LOCATION WHERE MEASUREMENTS WERE LESS THAN 0.9 pci/g

24

L

X

NOTE: PLUTONIUM CONCENTRATIONS WERE DERIVED FROM AMERICIUM CONCENTRATIONS WHICH IN TURN WERE DERIVED FROM IN SITU RADIOLOGICAL MEASUREMENTS (EDAG/EM, 1990).



Scale 1 = 300



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

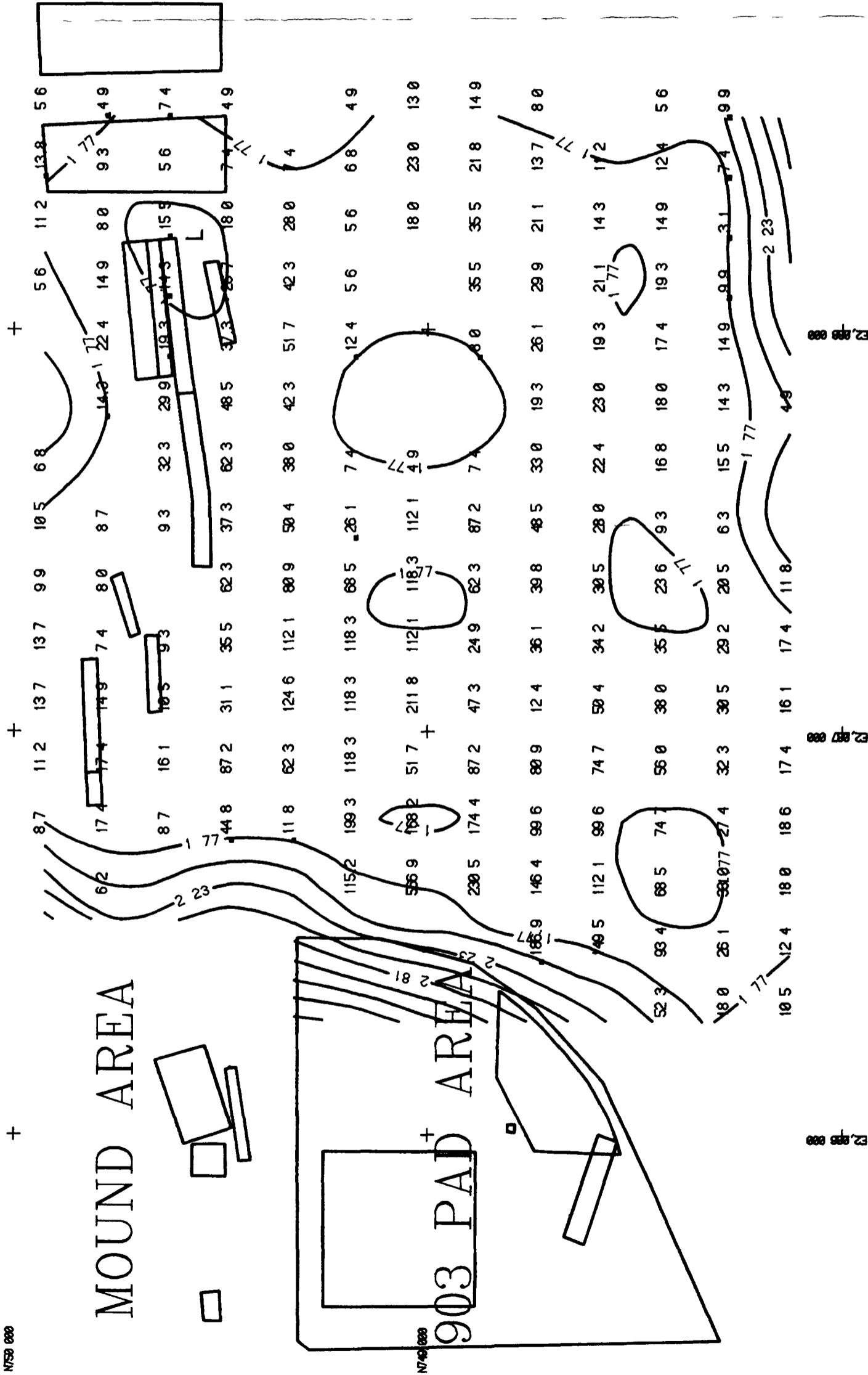
OPERABLE UNIT NO. 2
PHASE II REF/RI WORK PLAN (ALLUVIAL)

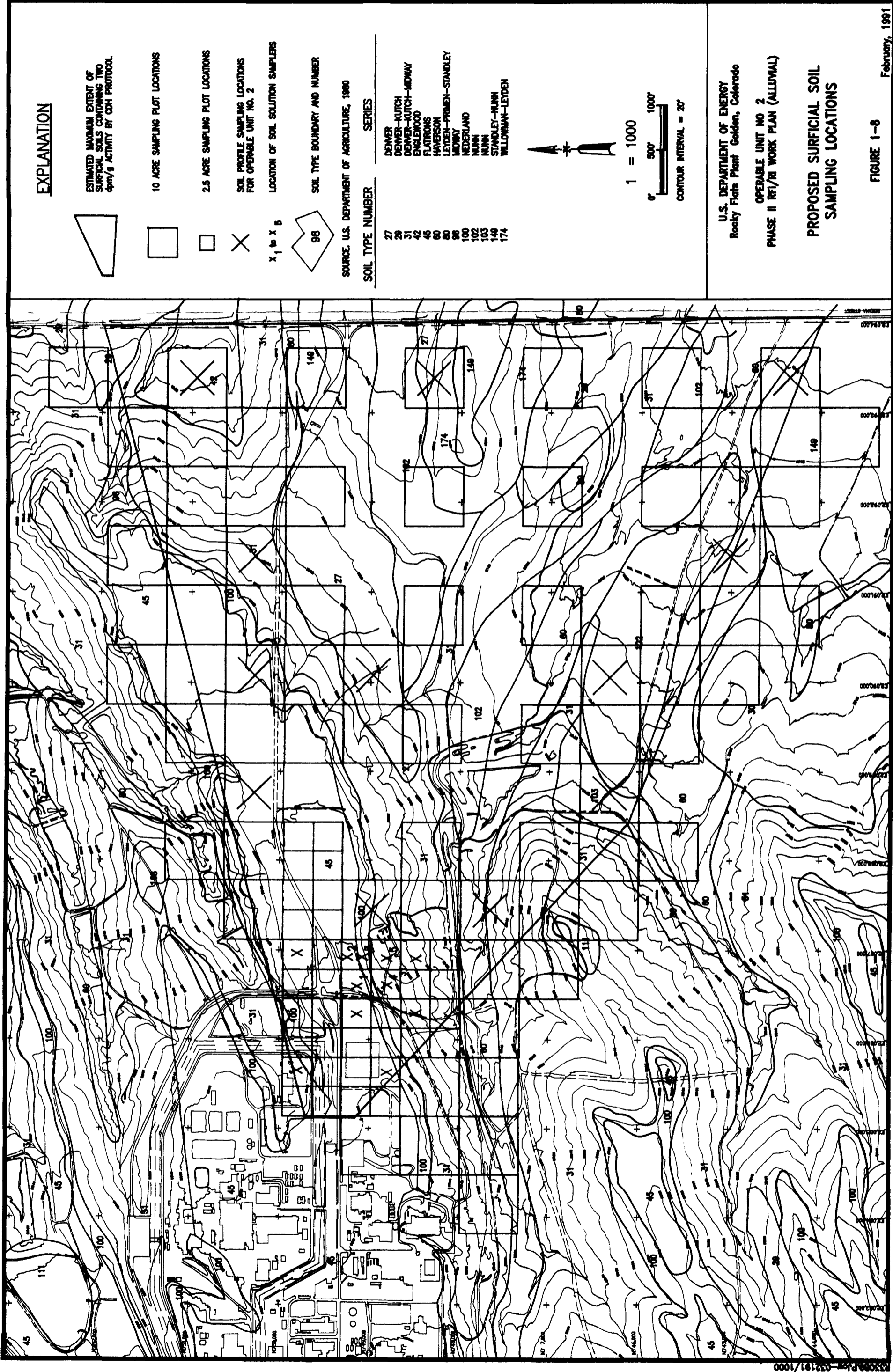
KRIGING STANDARD OF ERROR ESTIMATES
FOR PLUTONIUM IN SOILS
BASED ON 1990 STUDIES

FIGURE 1-7

February, 1991

EAST TRENCHES AREA



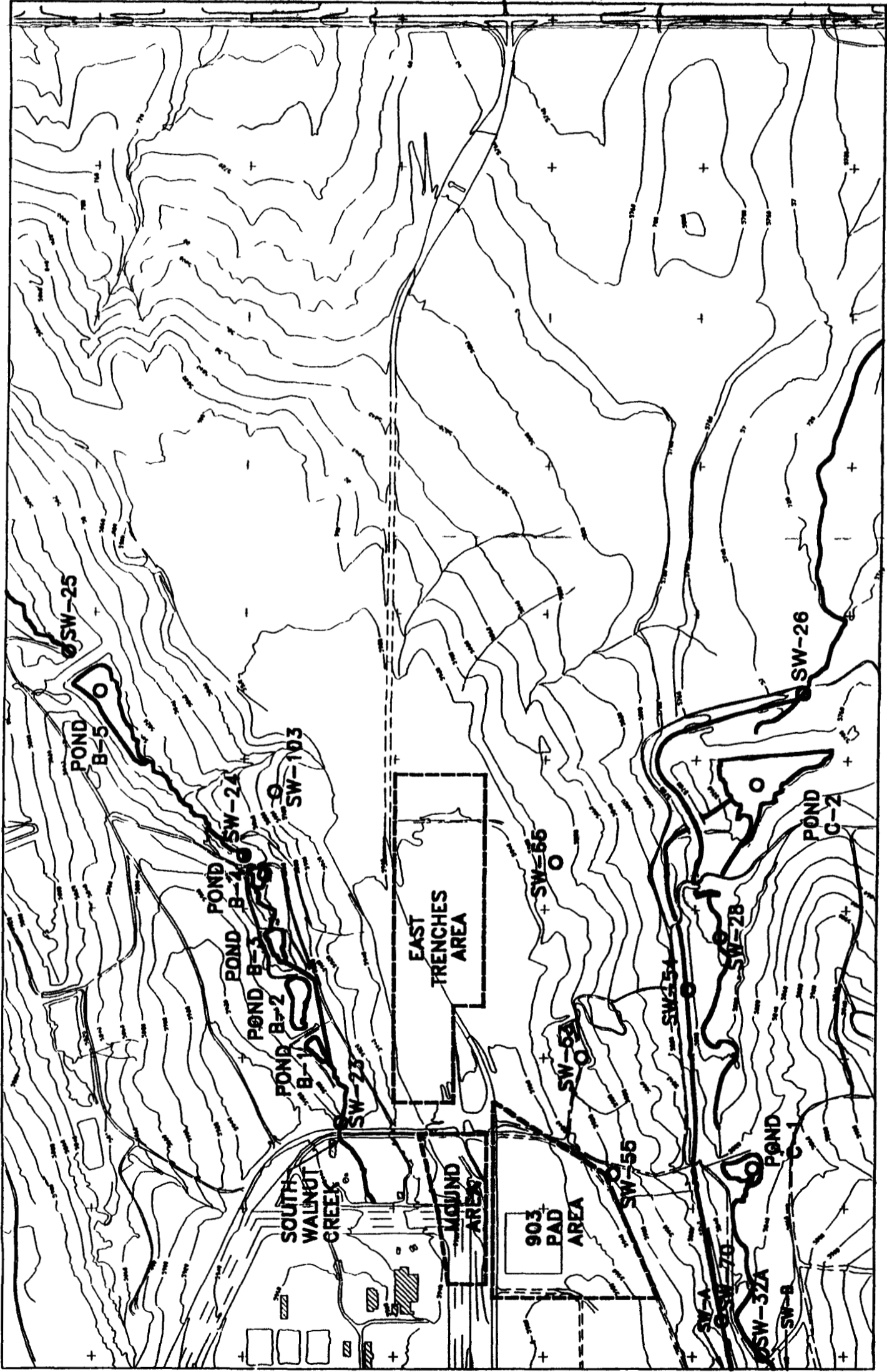


EXPLANATION

SOURCE AREAS



SAMPLING STATION



Scale 1" = 800'



CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO. 2
PHASE II BFT/BI WORK PLAN (ALLUVIAL)

AQUATIC ECOLOGY
SAMPLING STATIONS

FIGURE 2-1 February, 1981

EXPLANATION

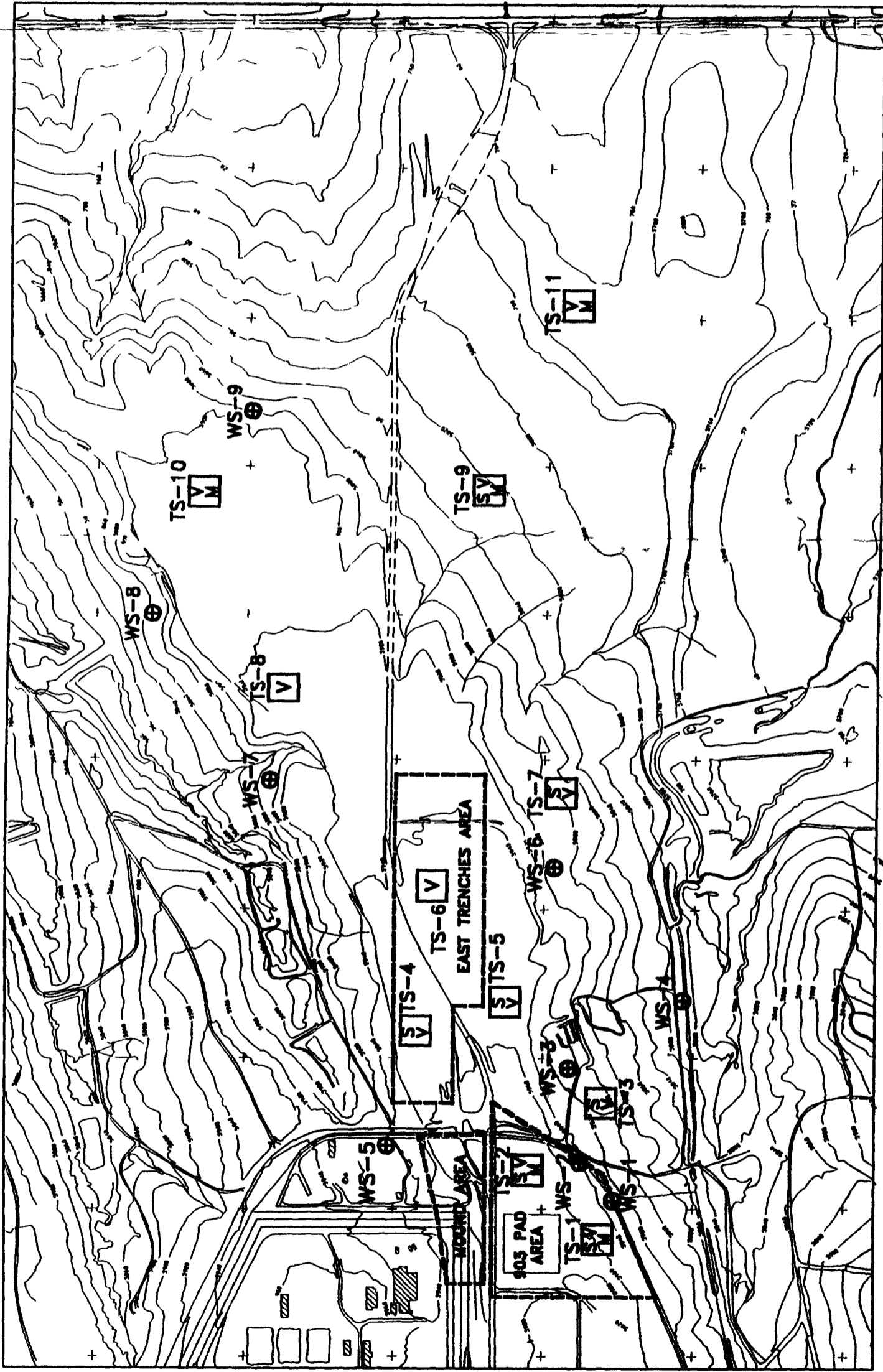
- SOURCE AREAS
- TS-1
- TERRESTRIAL SAMPLING LOCATION
- V -
- M -
- S -
- WS-7
- WETLAND SAMPLING LOCATION
- GRASSLAND VEGETATION PLOTS
- SMALL MAMMAL TRAPPING STATION
- SOIL ROOT SAMPLING LOCATION



Scale 1" = 800'

0' 400' 800'

CONTOUR INTERVAL = 20'



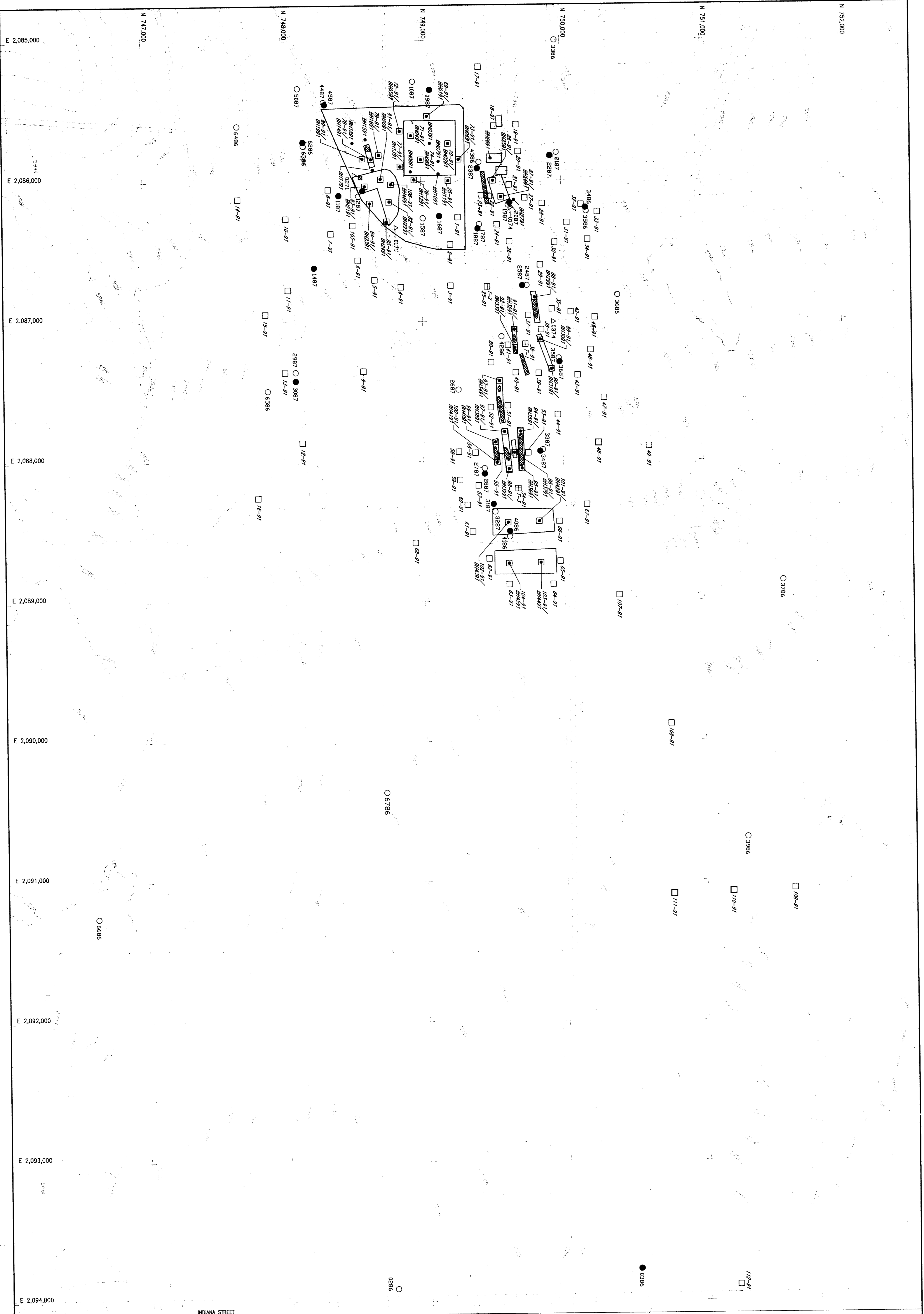
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RPT/RB WORK PLAN (ALLIANCE)

TERRESTRIAL AND WETLAND
SAMPLING STATIONS

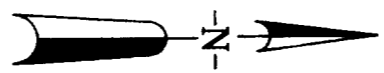
FIGURE 2-2

February, 1981



EXPLANATION

- 4587 ● BEDROCK MONITOR WELL
- 4487 ○ ALLUVIAL MONITOR WELL
- 25-91/ BH/181 ■ PROPOSED SOURCE CHARACTERIZATION ALLUVIAL MONITOR WELL AND BOREHOLE
- 6-91 □ PROPOSED PLUME CHARACTERIZATION ALLUVIAL MONITOR WELL
- BH/1791 • PROPOSED SOURCE CHARACTERIZATION BOREHOLE
- 1-2 + PROPOSED HYDRAULIC TEST LOCATION
- INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION
- LOCATION OF BARRELS DETERMINED BY VISUAL INSPECTION OR MAGNETOMETER SURVEY



SCALE: 1 INCH = 300 FEET
300' 0 300'
CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI WORK PLAN (ALLUVIAL)

EXISTING AND PROPOSED PHASE II RFI/RI
MONITOR WELL AND
BOREHOLE LOCATIONS

PLATE 1